FIG. 1

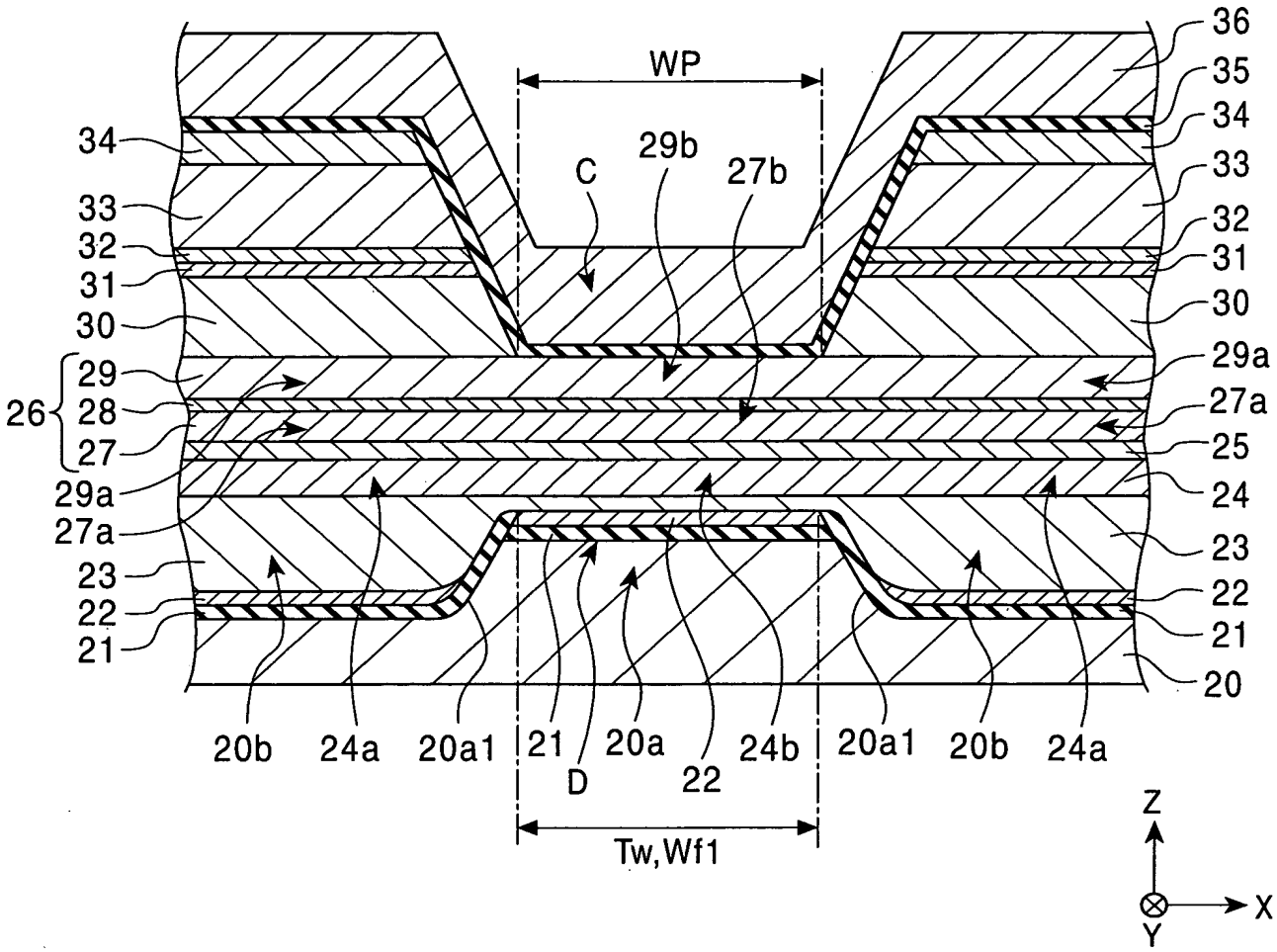

WP
C
29b
27b
36
35
34
33
32
31
30
29a
27a
25
24
23
22
21
20
26
29
28
27
20b
24a
20a1
21
D
20a
22
24b
Tw,Wf1
Z
X
Y

FIG. 2

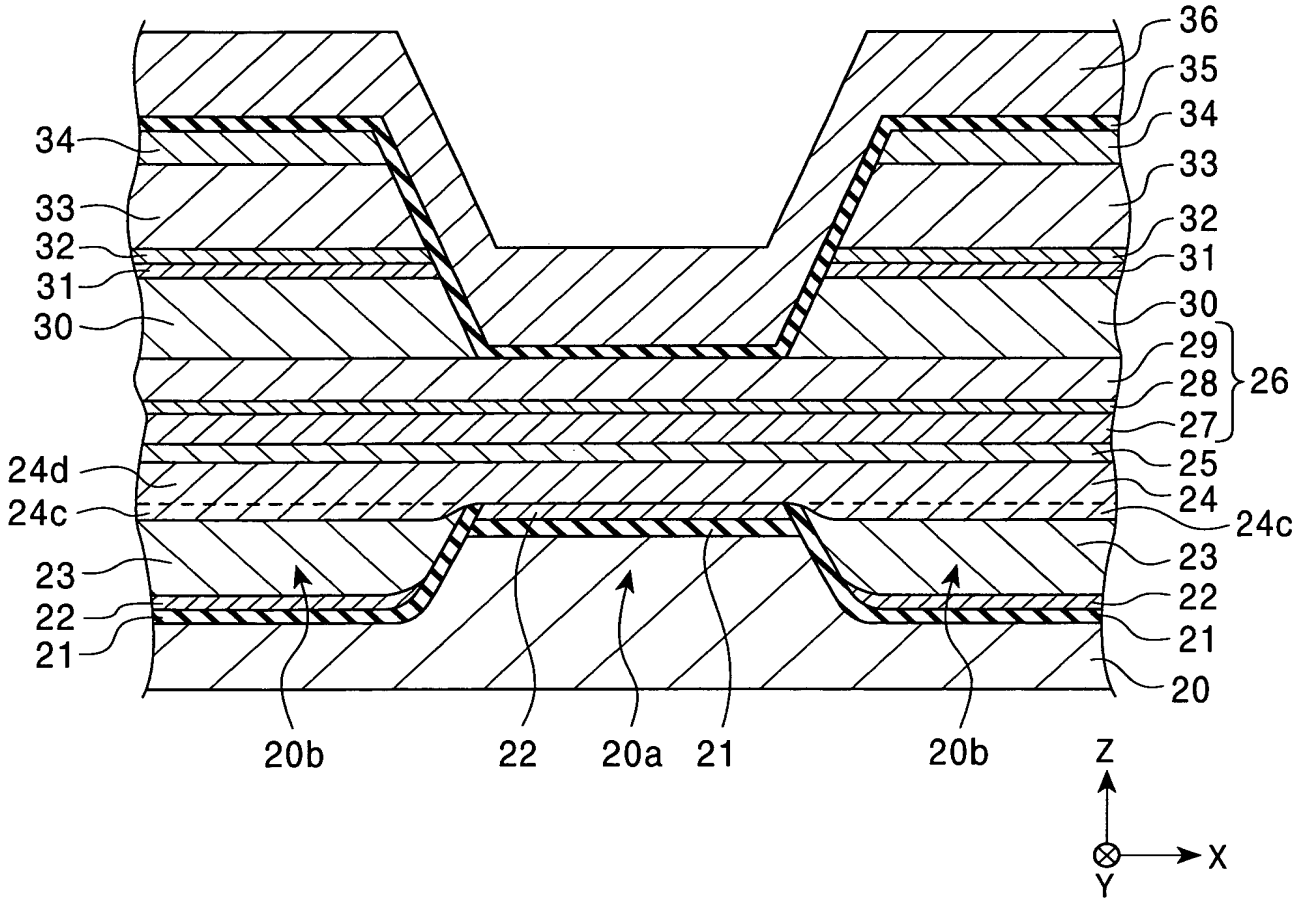

36
35
34
33
32
31
30
29
28
27
26
25
24
24c
23
22
21
20
34
33
32
31
30
24d
24c
23
22
21
20b
22
20a
21
20b
Z
X
Y

FIG. 3

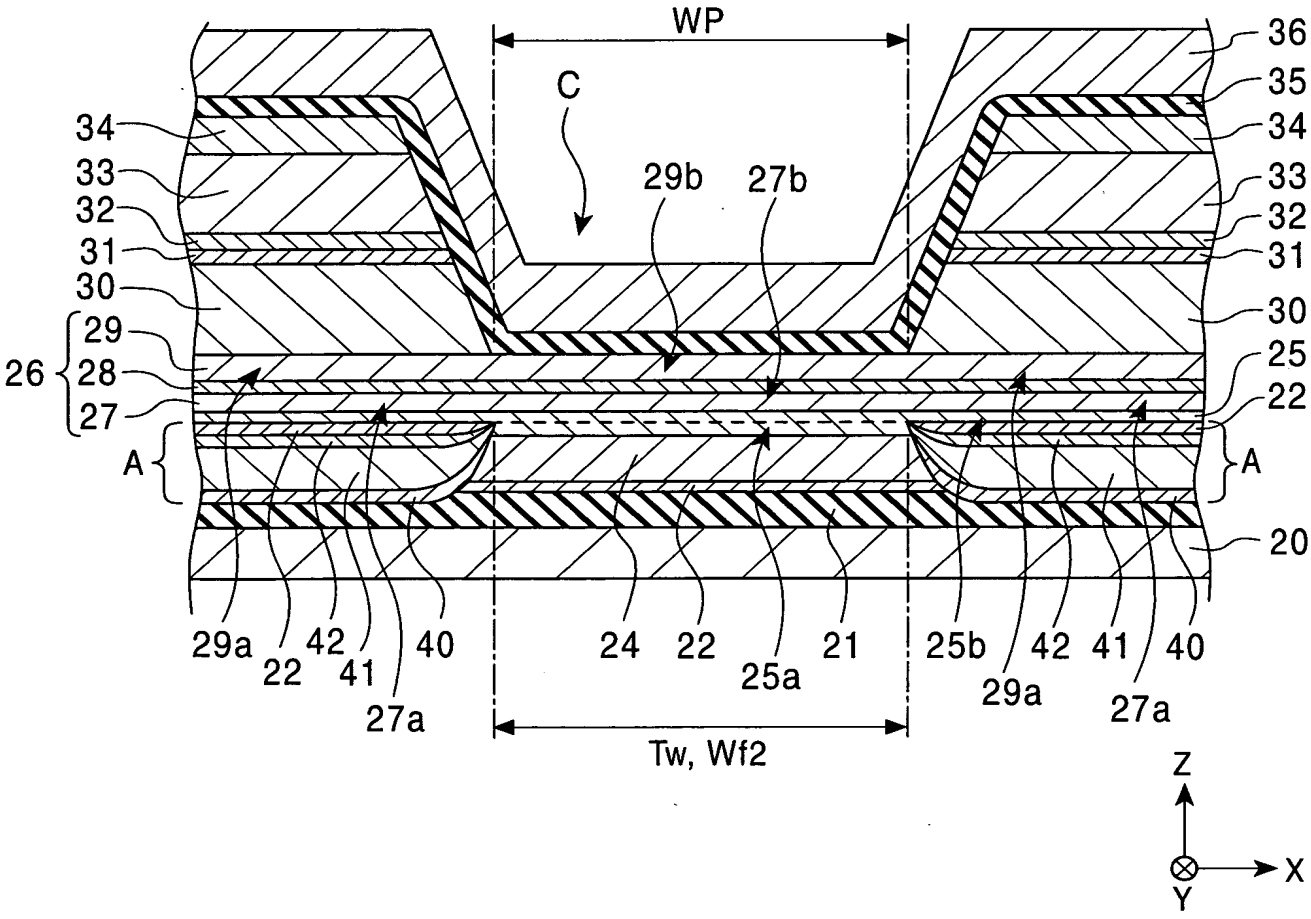
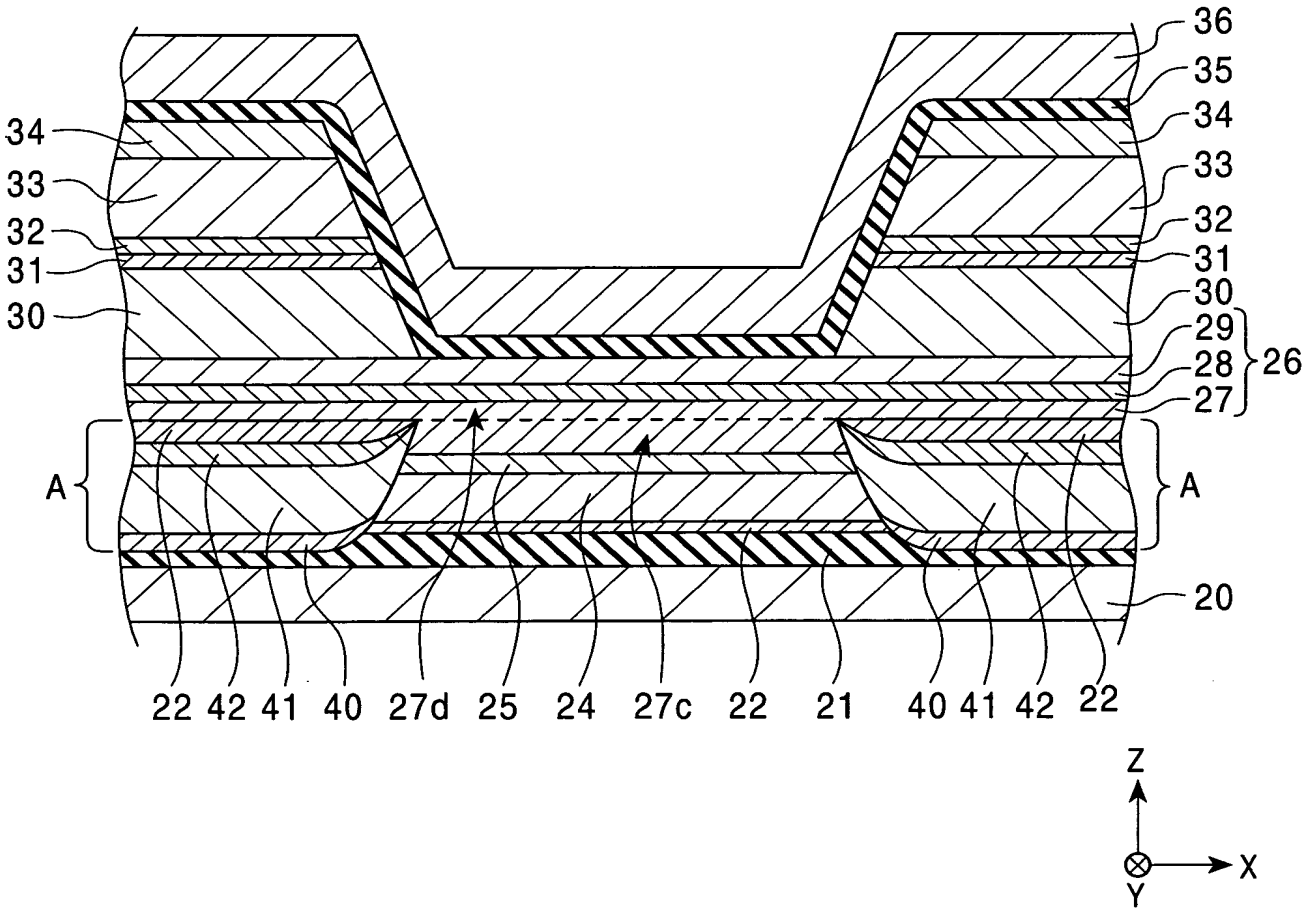

WP
C
29b
27b
36
35
34
33
32
31
30
29
26
28
27
25
22
A
A
20
29a
22
42
41
40
27a
24
22
25a
21
25b
29a
42
41
40
27a
Tw, Wf2
Z
X
Y

FIG. 4


36
35
34
33
32
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30
29
28
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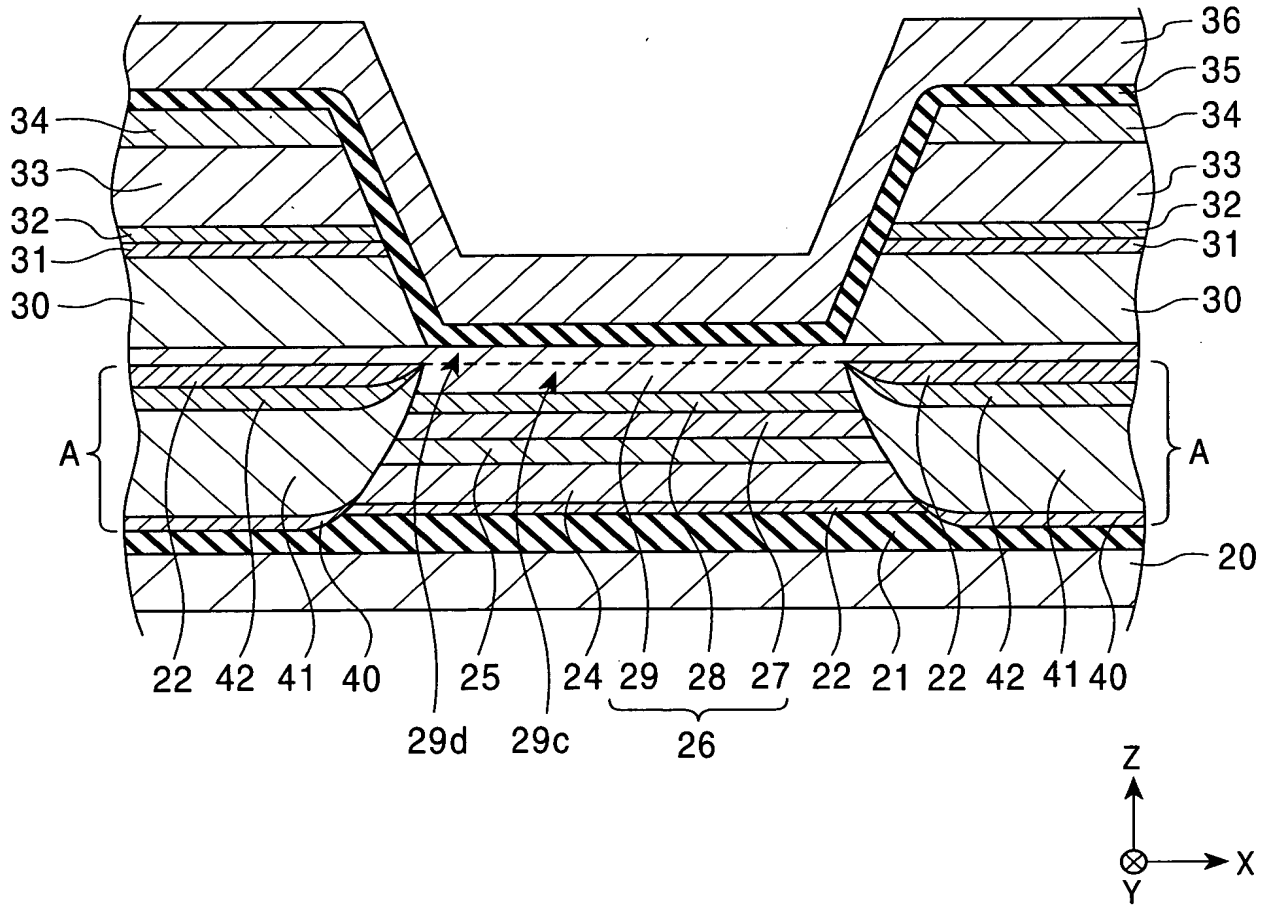
31
30
A
A
20
22 42 41 40 27d 25 24 27c 22 21 40 41 42 22
Z
X
Y

FIG. 5


36
35
34
33
32
31
30
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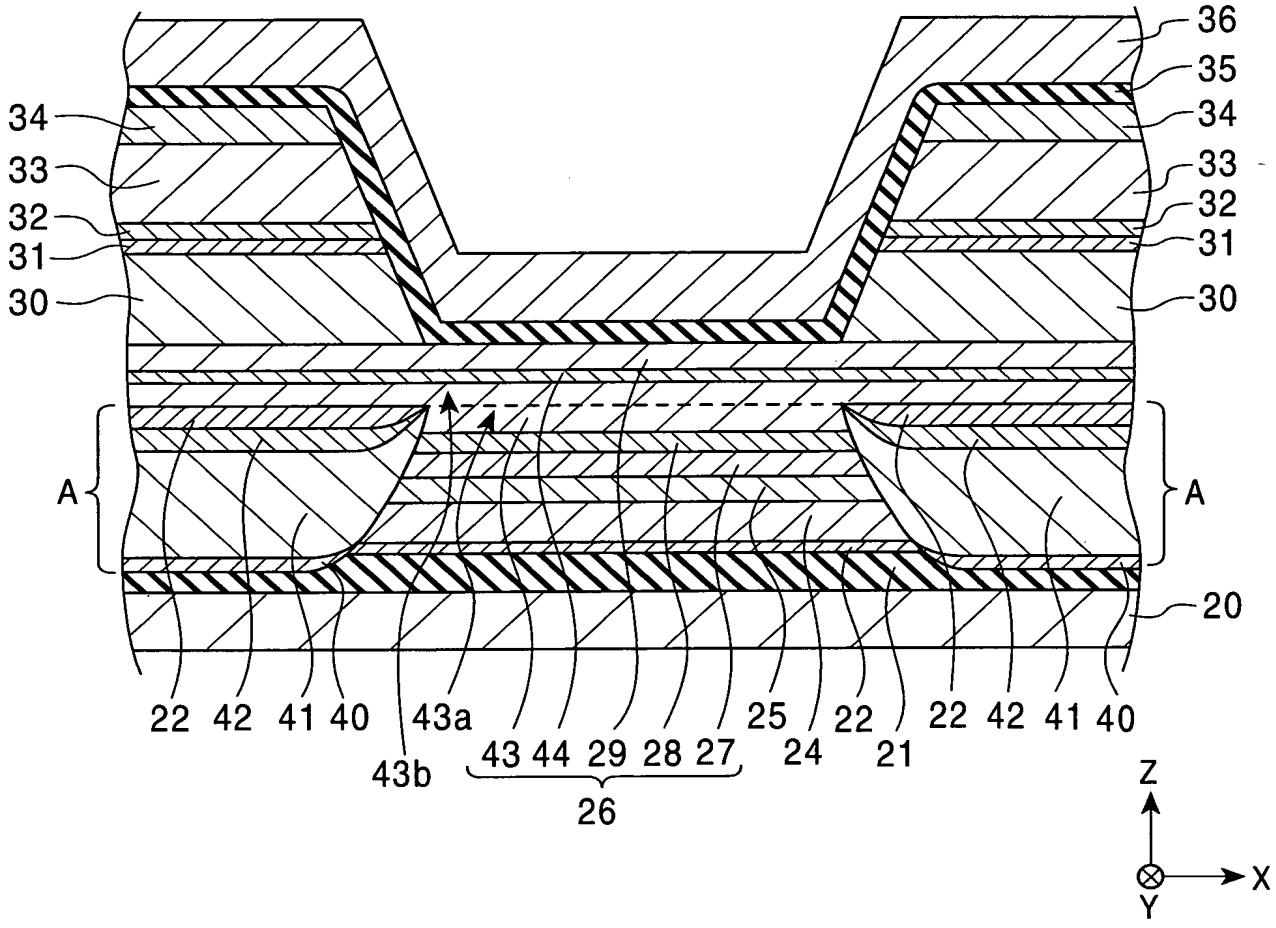
A
A
20
22 42 41 40 25 24 29 28 27 22 21 22 42 41 40
29d 29c 26
Z
X
Y

FIG. 6


36
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32
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A
A
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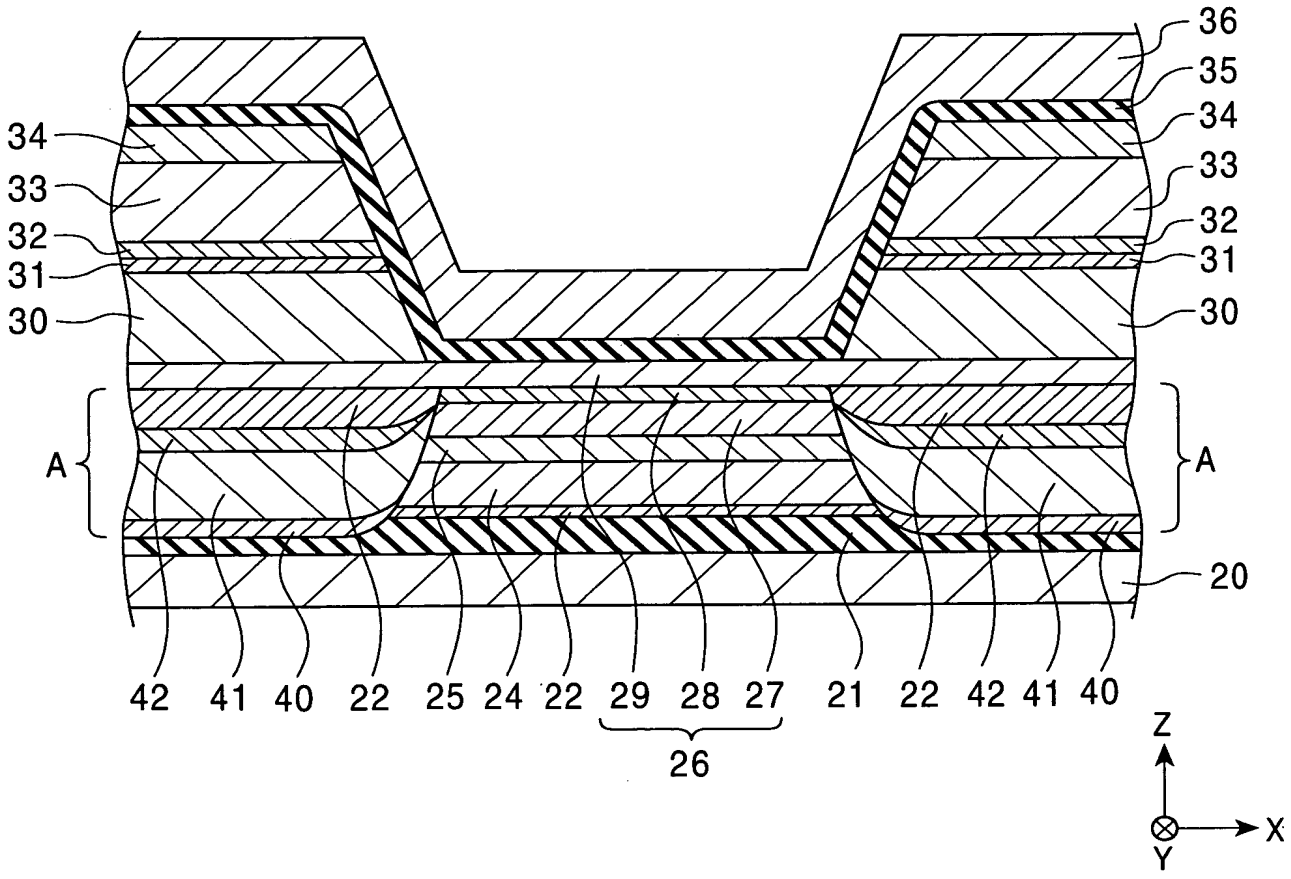
22 42 41 40 43a 25 22 22 42 41 40
43b 43 44 29 28 27 24 21
26
Z
X
Y

FIG. 7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32
31
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A
A
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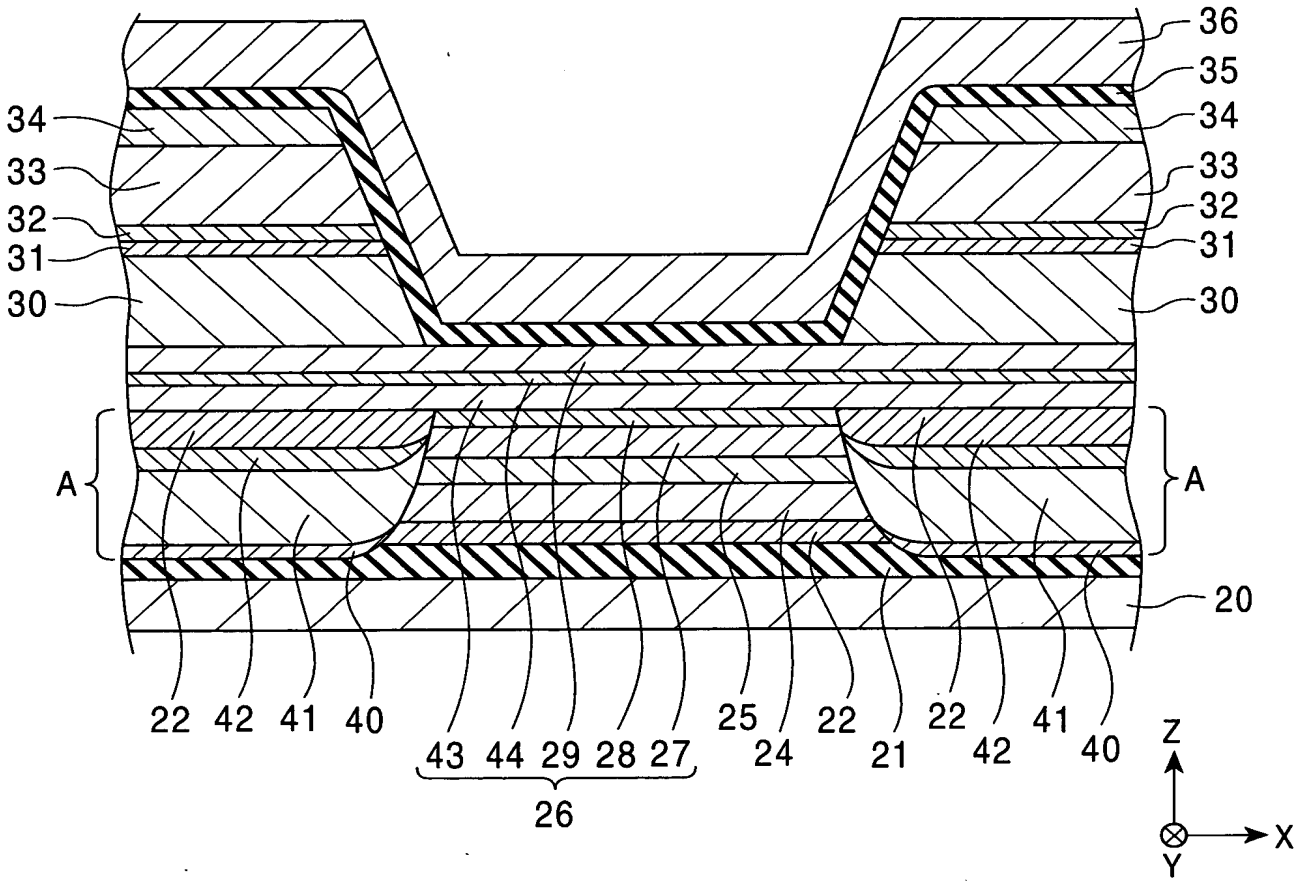
22
29
28
27
21
22
42
41
40
26
Z
X
Y

FIG. 8


36
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32
31
30
34
33
32
31
30
A
A
20
22
42
41
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43
44
29
28
27
26
25
24
22
21
22
42
41
40
Z
X
Y

FIG. 9

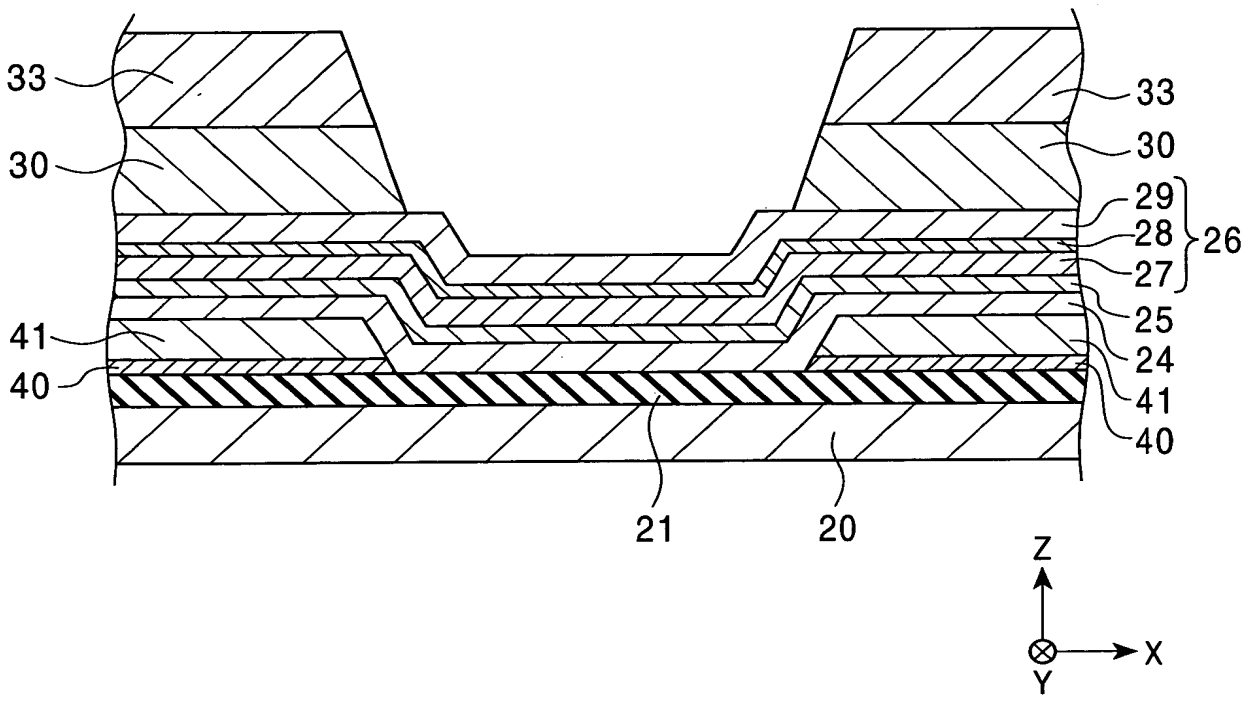


FIG. 10

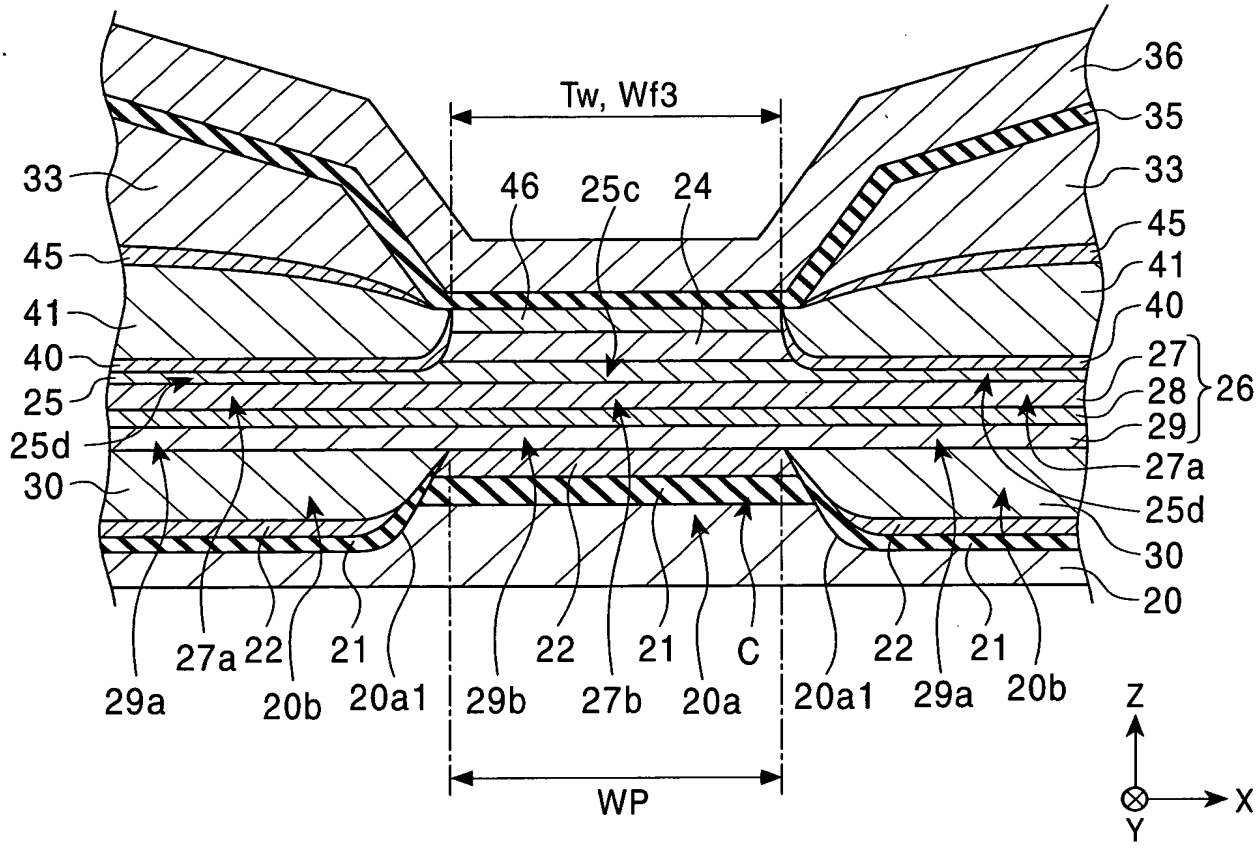

Tw, Wf3
36
35
33
46
25c
24
33
45
45
41
41
40
40
27
25
28
26
29
25d
27a
30
25d
30
20
29a
27a
22
20b
21
20a1
29b
22
27b
21
20a
C
20a1
22
29a
21
20b
WP
Z
X
Y

FIG. 11

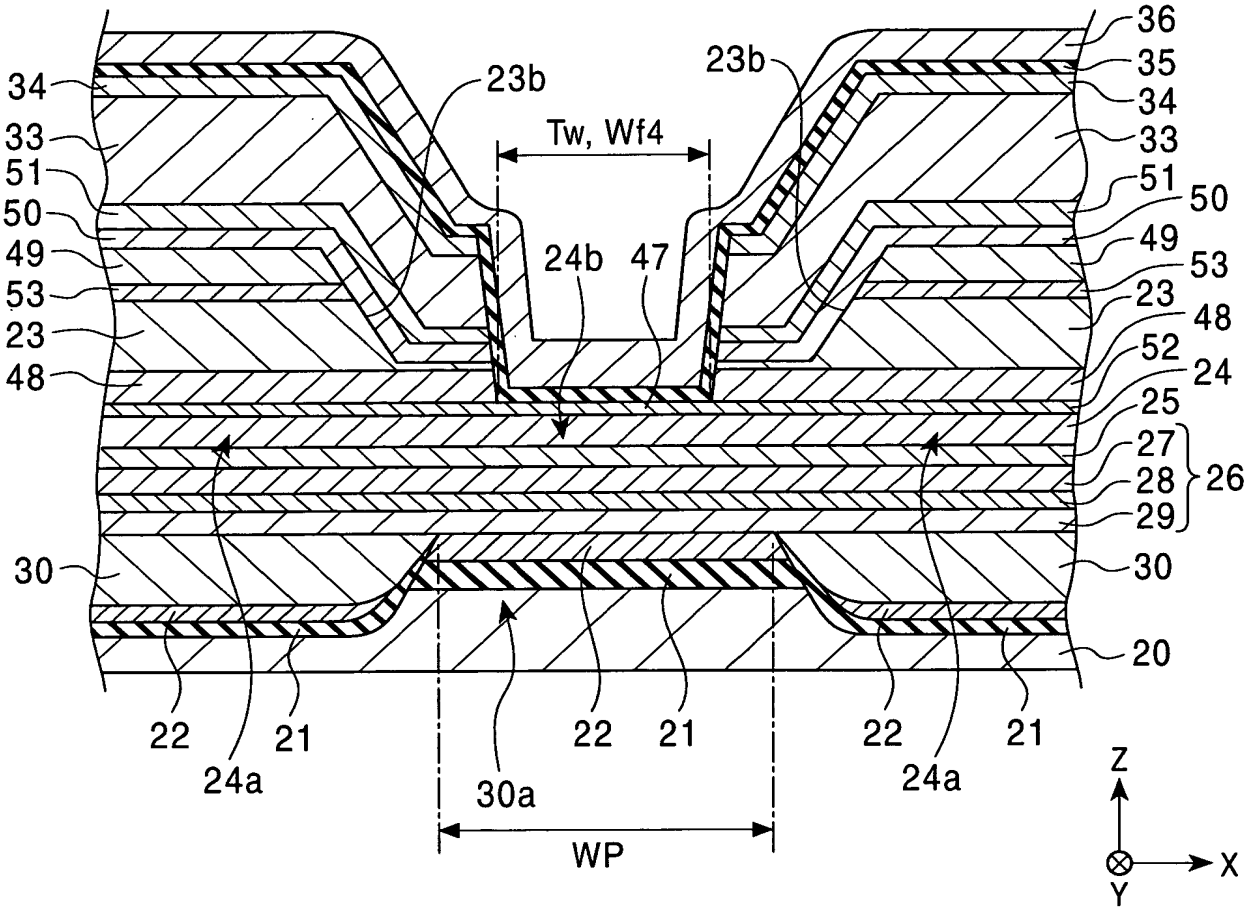

34
33
51
50
49
53
23
48
30
23b
Tw, Wf4
24b
47
23b
36
35
34
33
51
50
49
53
23
48
52
24
25
27
28
29
26
30
20
22
24a
21
30a
22
21
WP
22
24a
21
Z
X
Y

FIG. 12

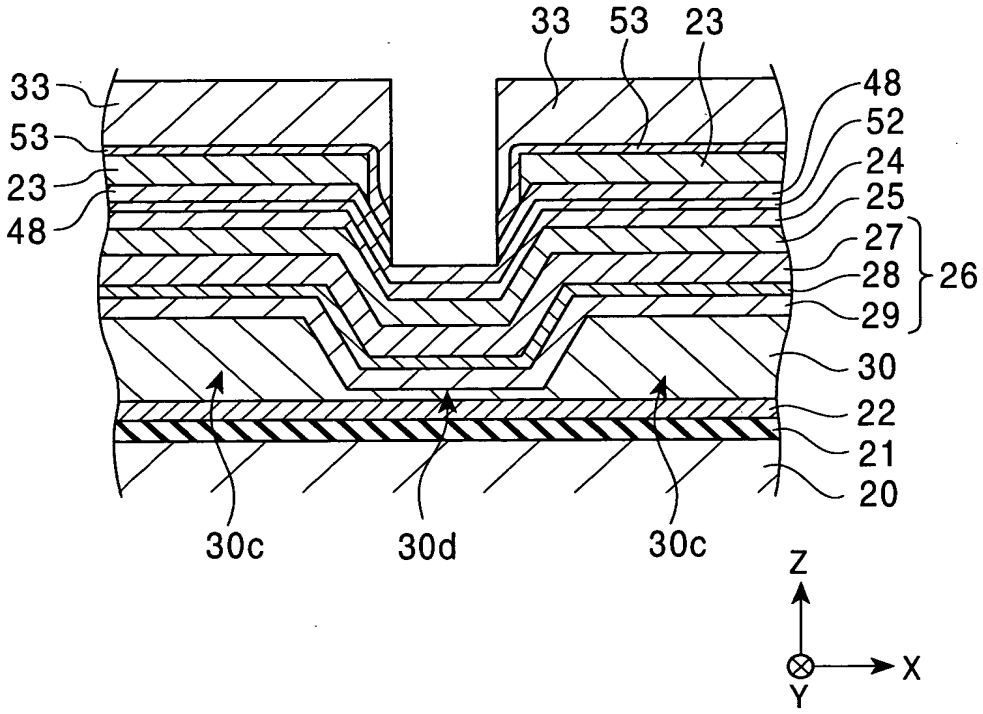

33
53
23
48
33
53
23
48
52
24
25
27
28
29
26
30
22
21
20
30c
30d
30c
Z
X
Y

FIG. 13

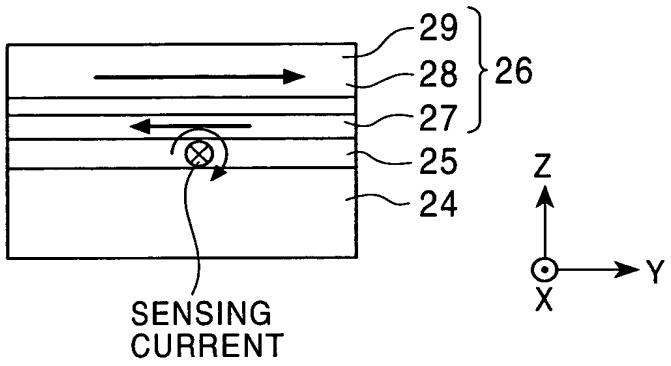


FIG. 14

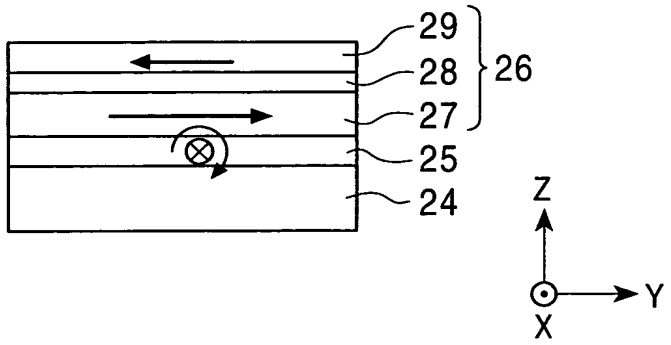
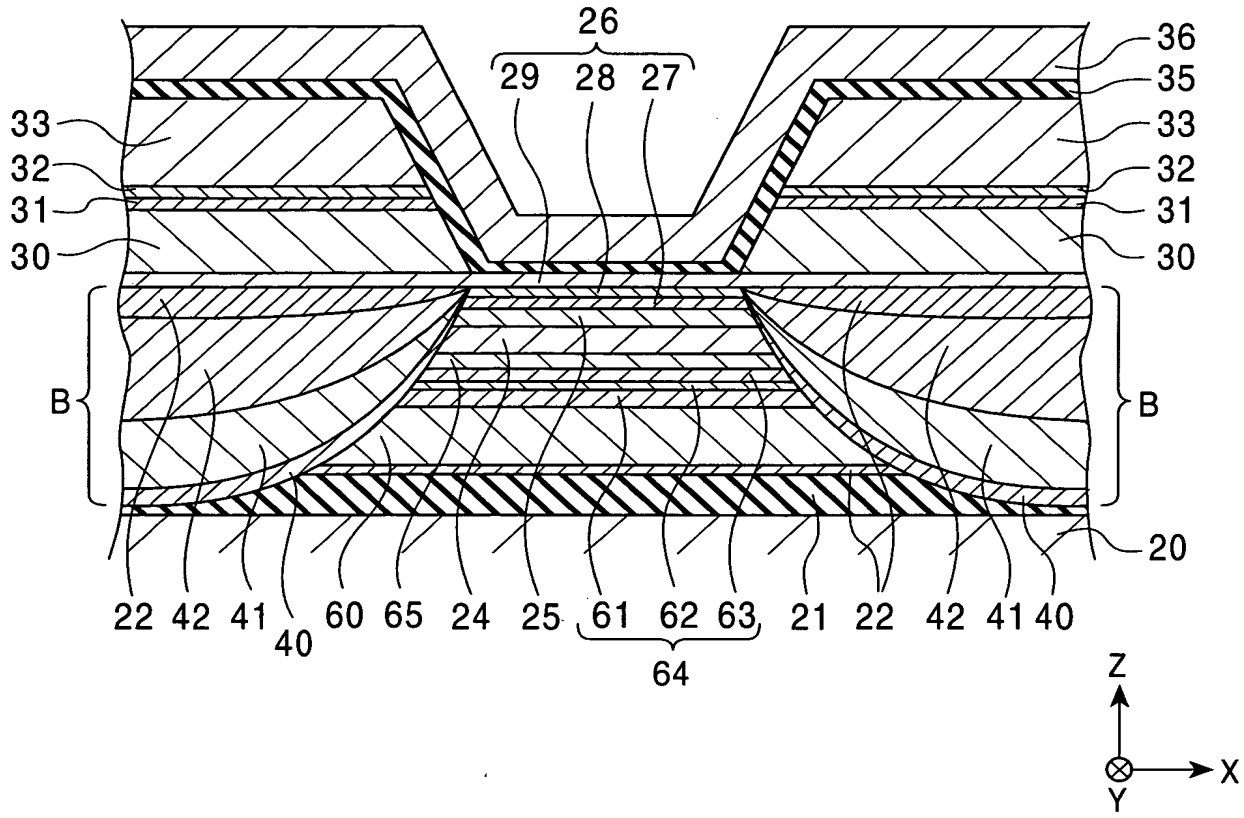


FIG. 15


26
29
28
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32
31
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30
B
B
20
22
42
41
40
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65
24
25
61
62
63
64
21
22
42
41
40
Z
X
Y

FIG. 16

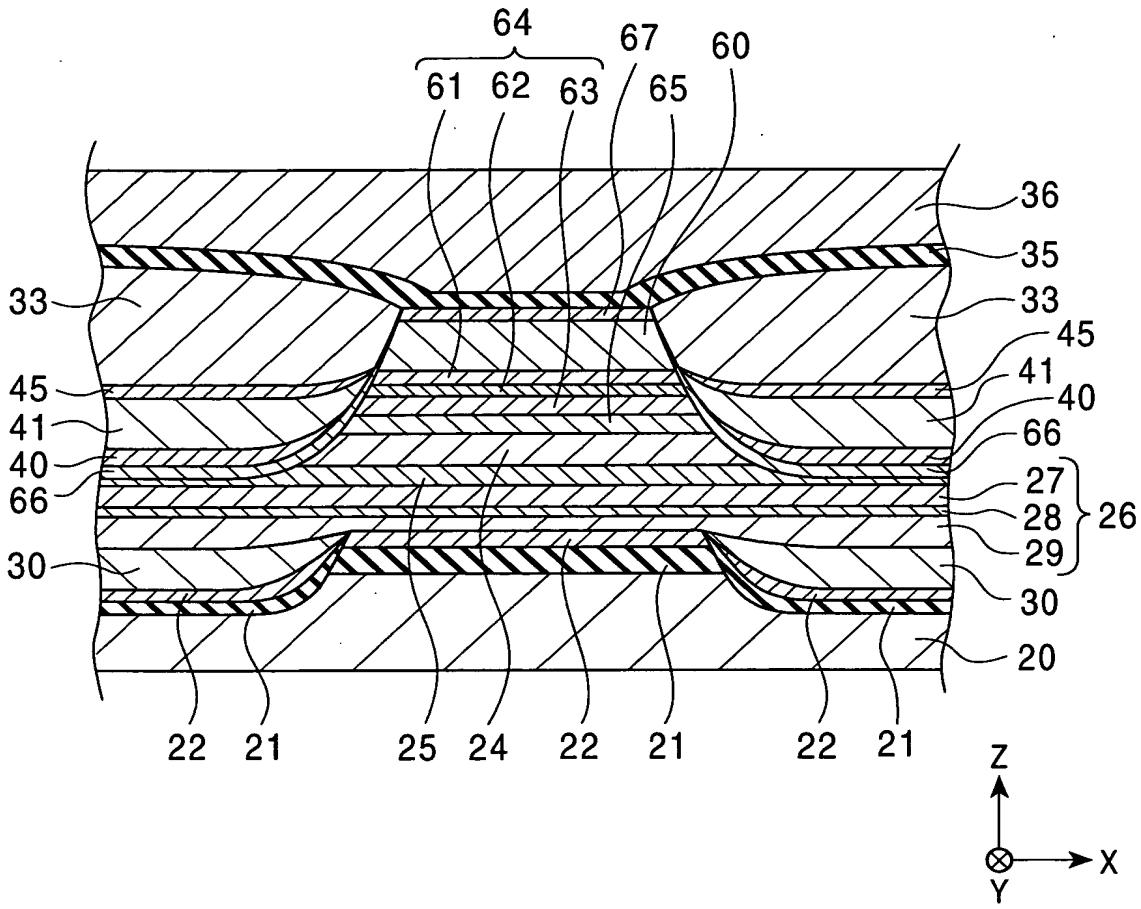
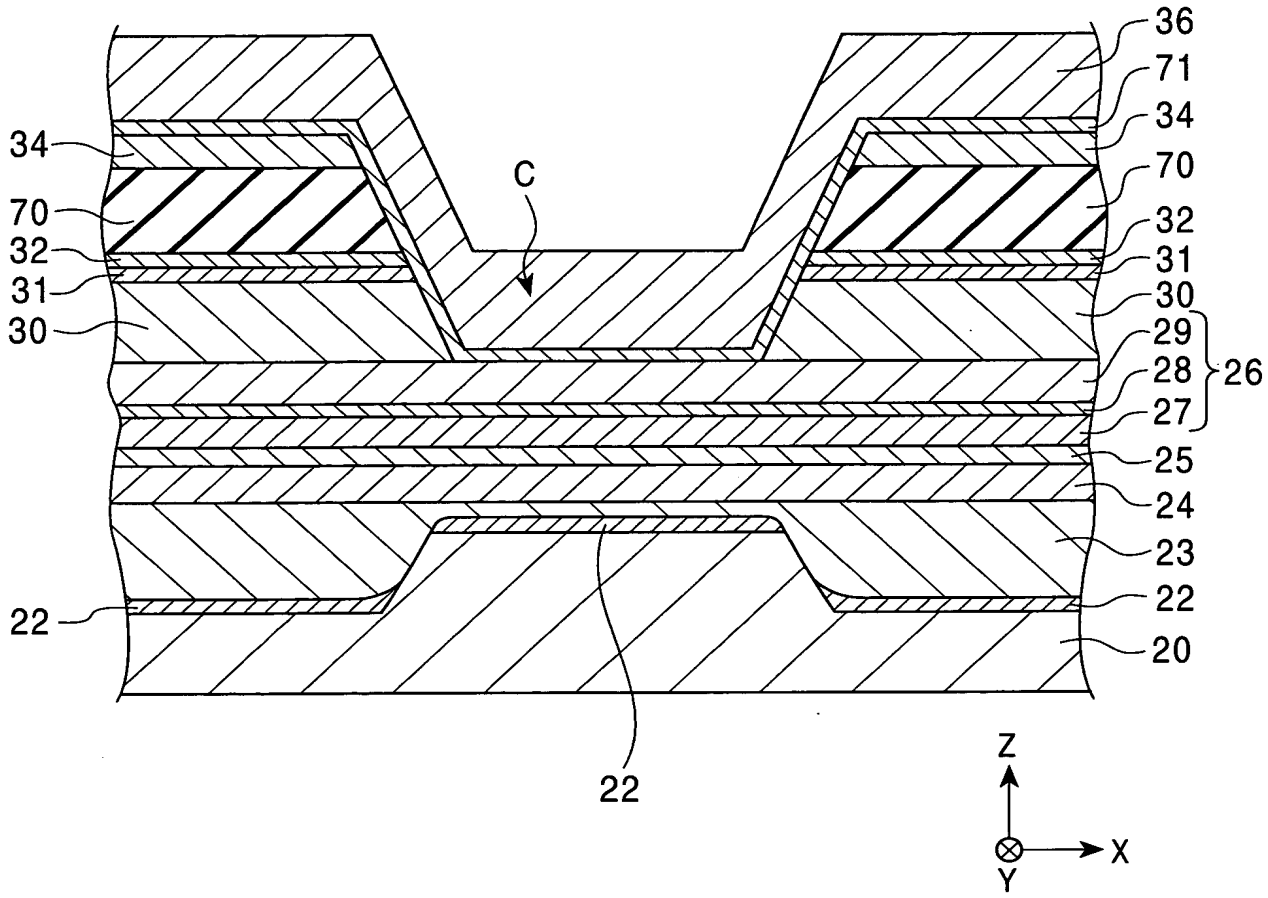

64
67
60
61
62
63
65
36
35
33
33
45
41
40
66
27
28
29
26
30
20
45
41
40
66
30
22
21
25
24
22
21
22
21
Z
X
Y

FIG. 17


36
71
34
70
32
31
30
29
28
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25
24
23
22
20
34
70
32
31
30
C
22
22
Z
X
Y

FIG. 18

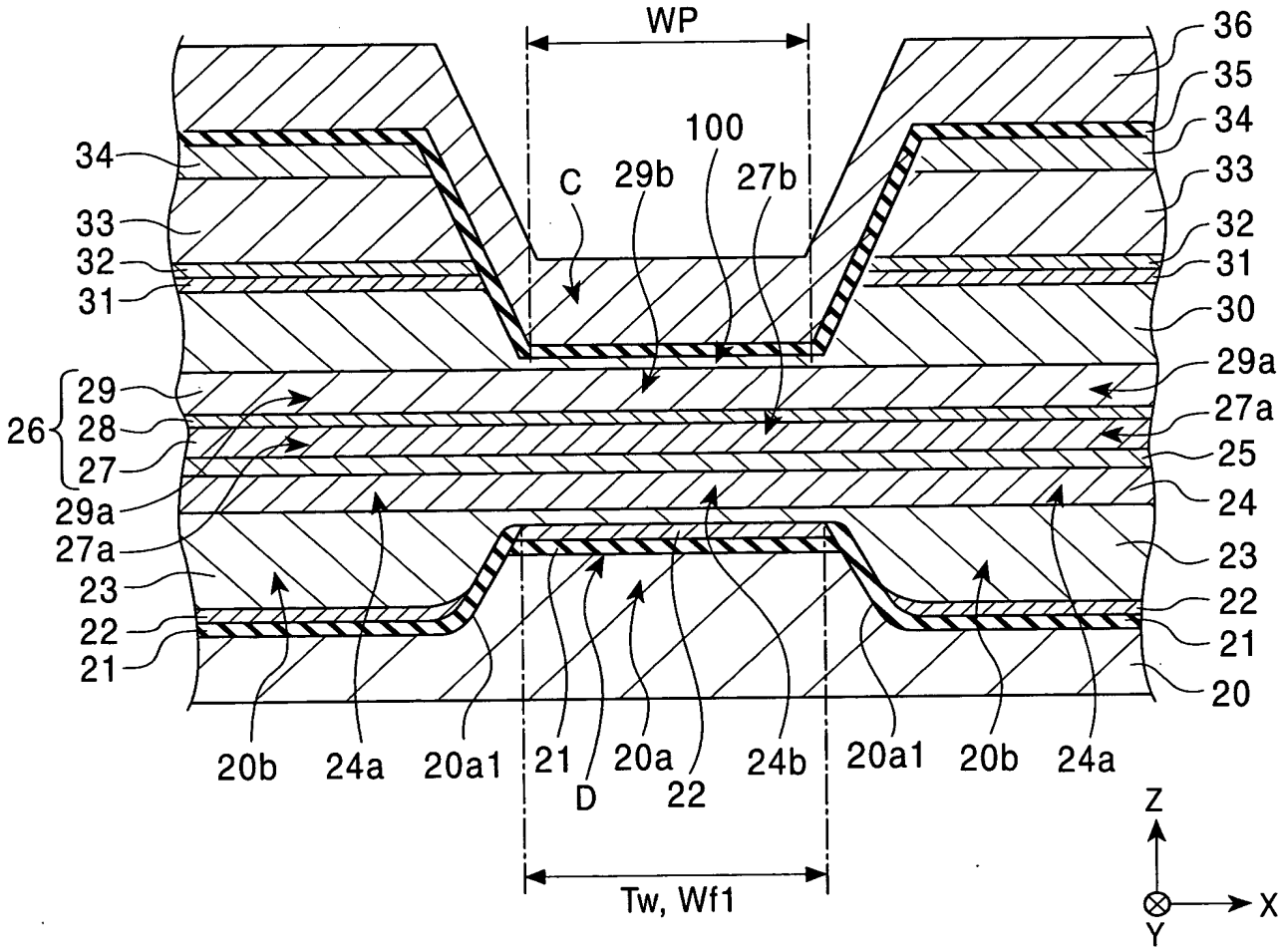
WP
100
C
29b
27b
34
33
32
31
30
29a
27a
25
24
23
22
21
20
36
35
26
29
28
27
20b
24a
20a1
21
D
20a
22
24b
Tw, Wf1
Z
X
Y

FIG. 19

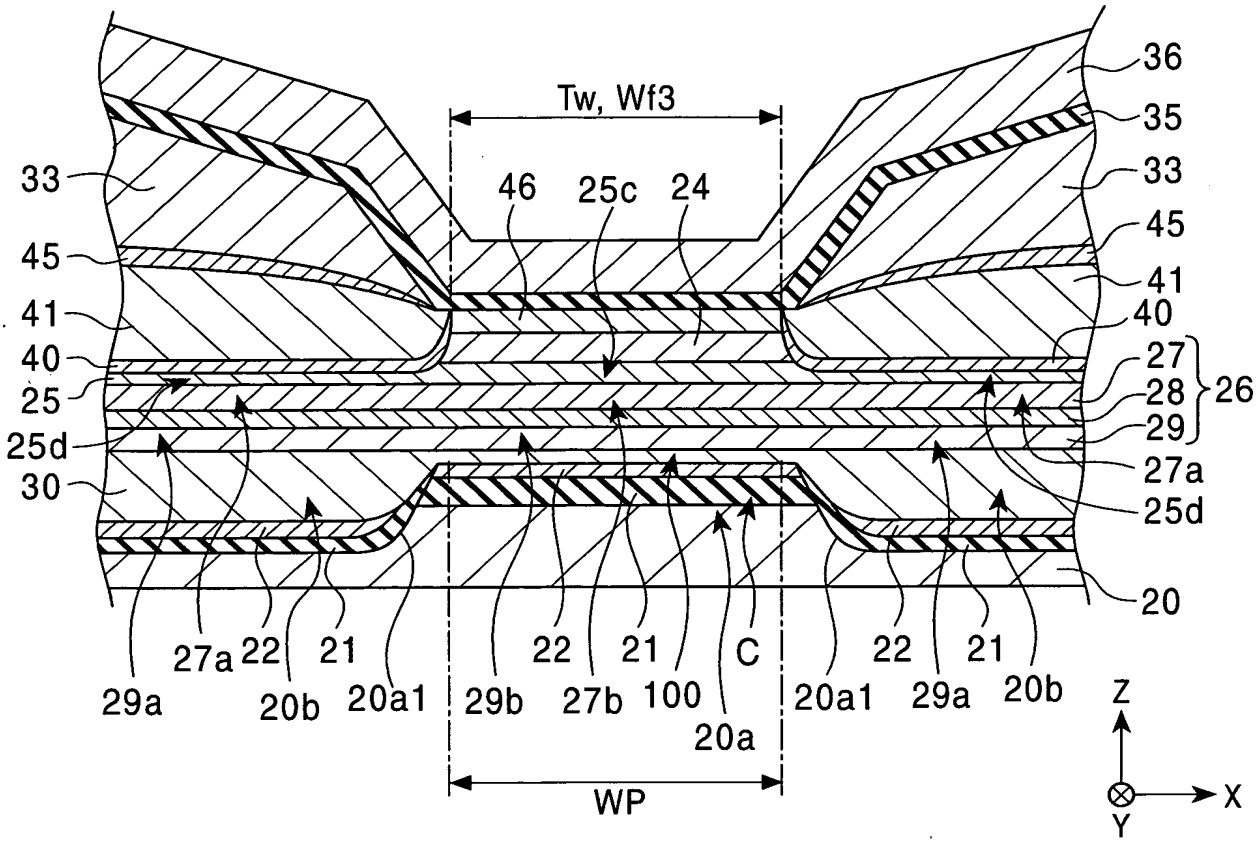
Tw, Wf3
36
35
33
46
25c
24
33
45
45
41
41
40
40
27
25
28
26
25d
29
30
27a
25d
20
29a
27a
22
21
20b
20a1
29b
22
27b
21
100
C
20a
20a1
22
29a
21
20b
WP
Z
X
Y

FIG. 20

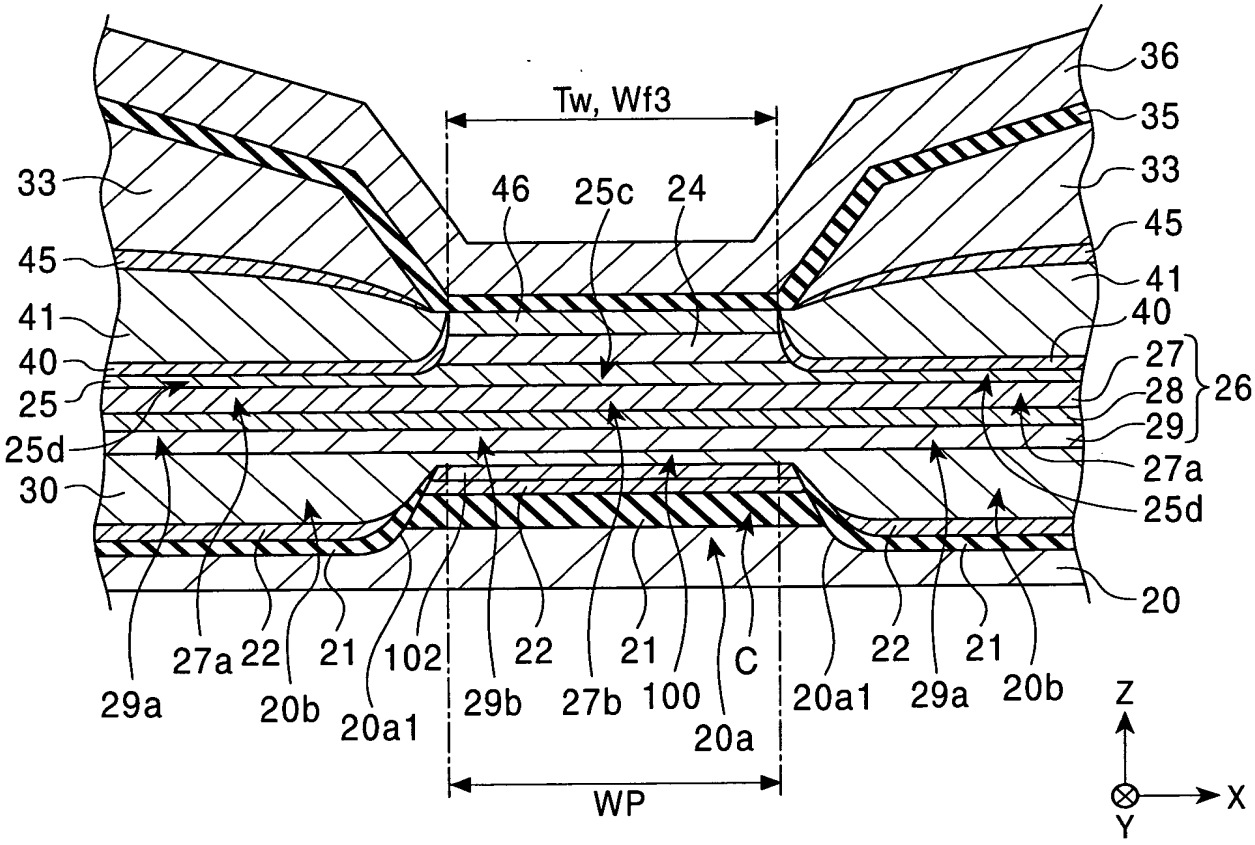
Tw, Wf3
36
35
33
46
25c
24
33
45
45
41
41
40
40
27
25
28
26
29
25d
27a
30
25d
20
29a
27a
22
20b
21
20a1
102
29b
22
27b
21
100
C
20a
20a1
22
29a
21
20b
WP
Z
X
Y

FIG. 21

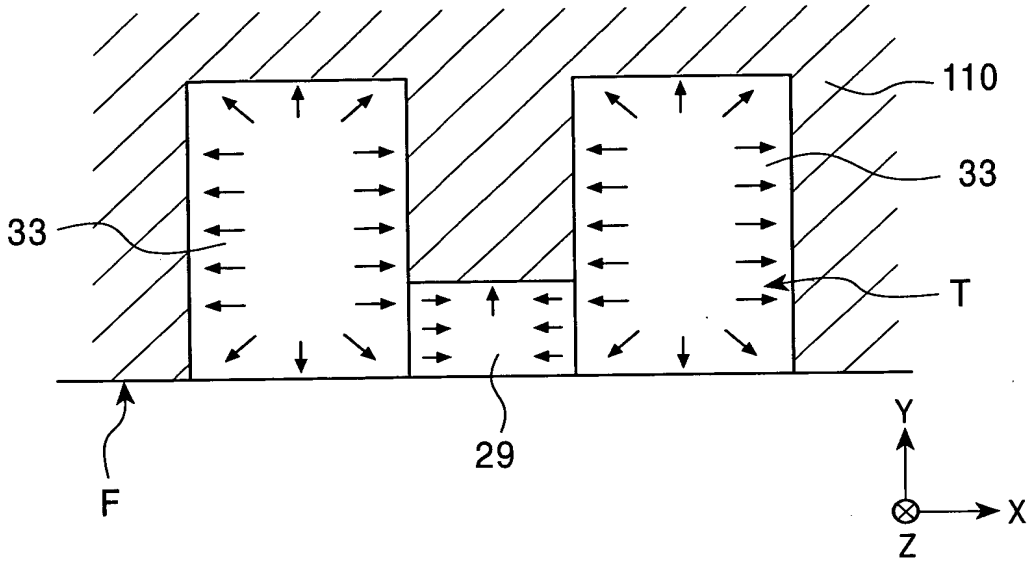

FIG. 22

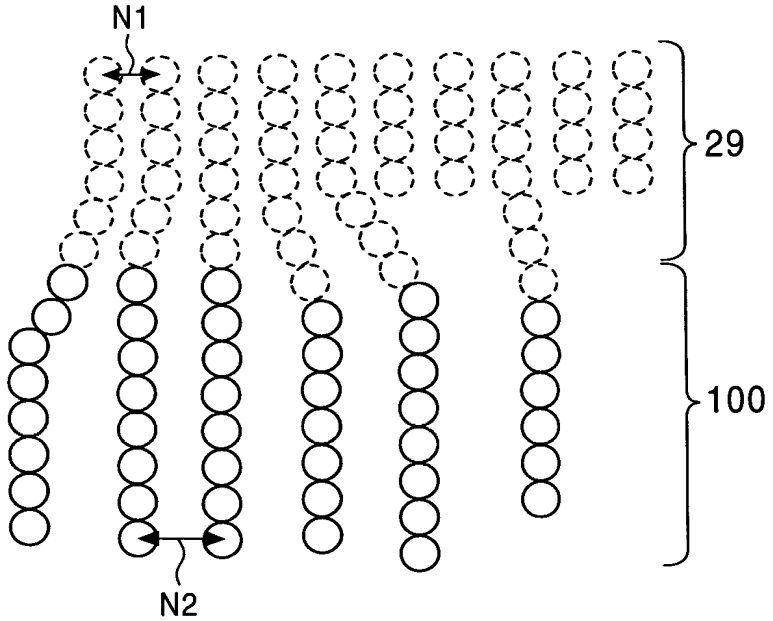

FIG. 23

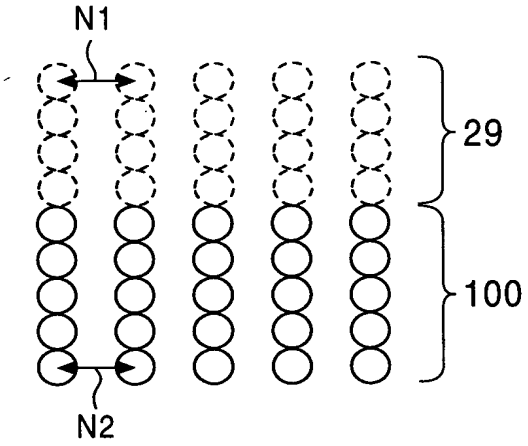

FIG. 24

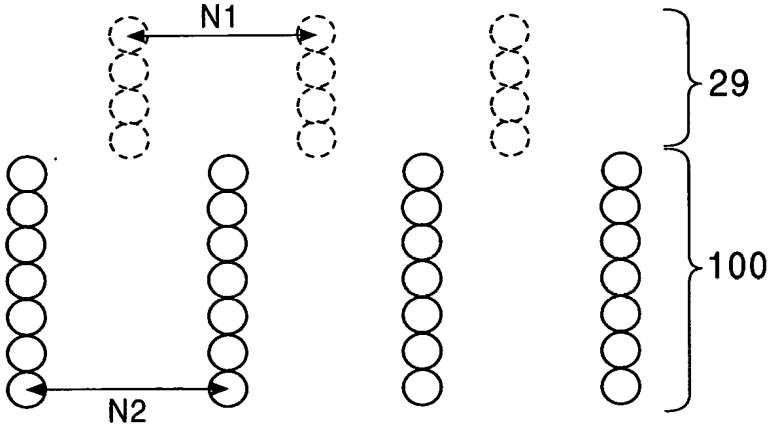

FIG. 25

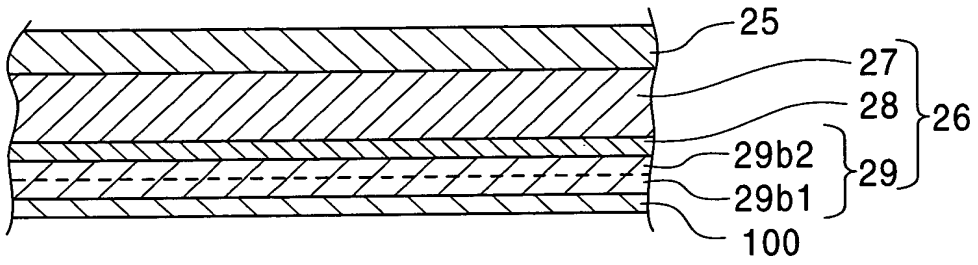

FIG. 26

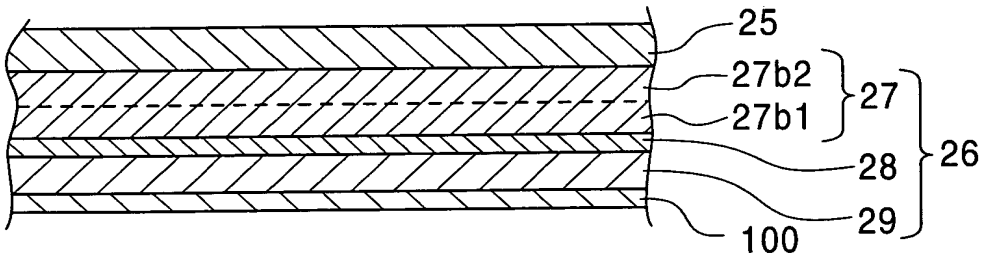

FIG. 27

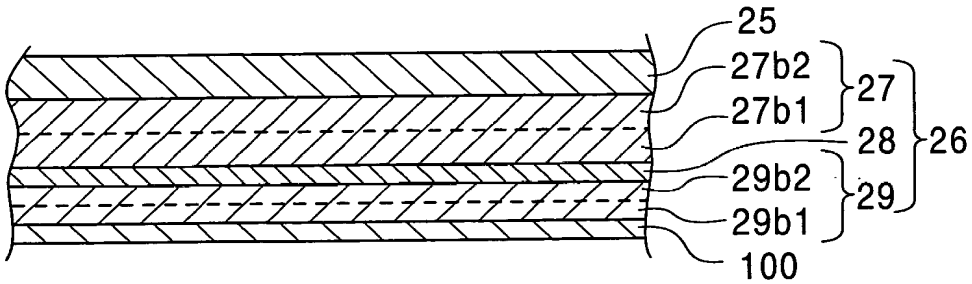

FIG. 28

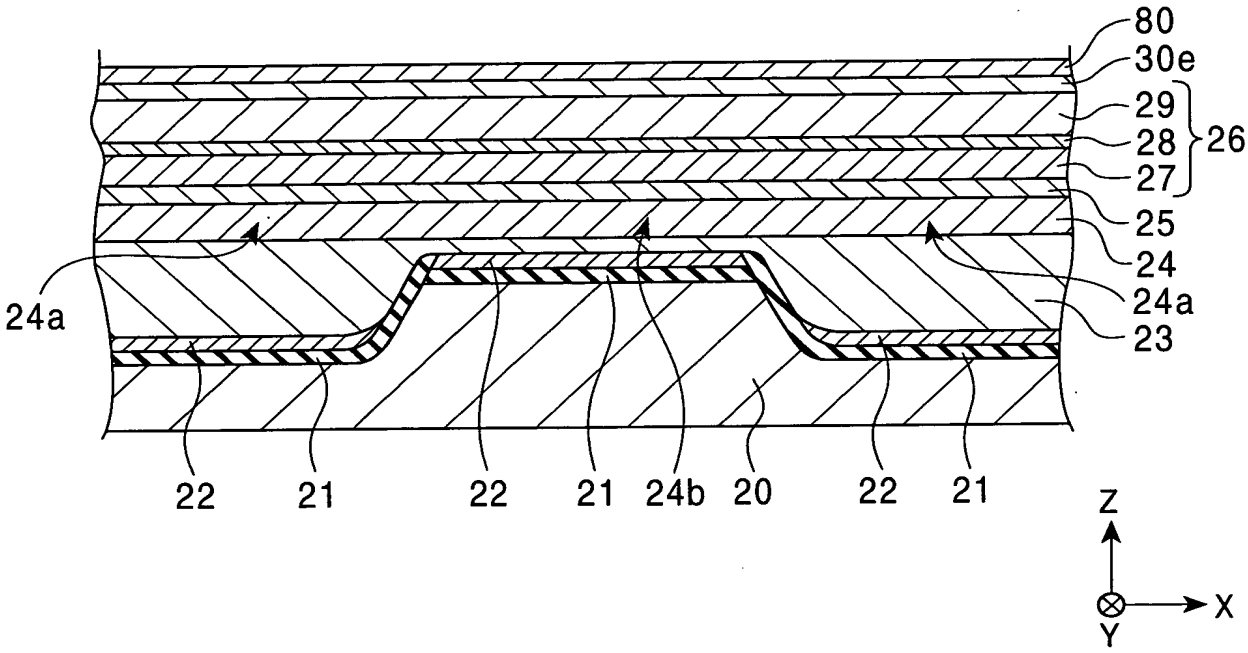

FIG. 29

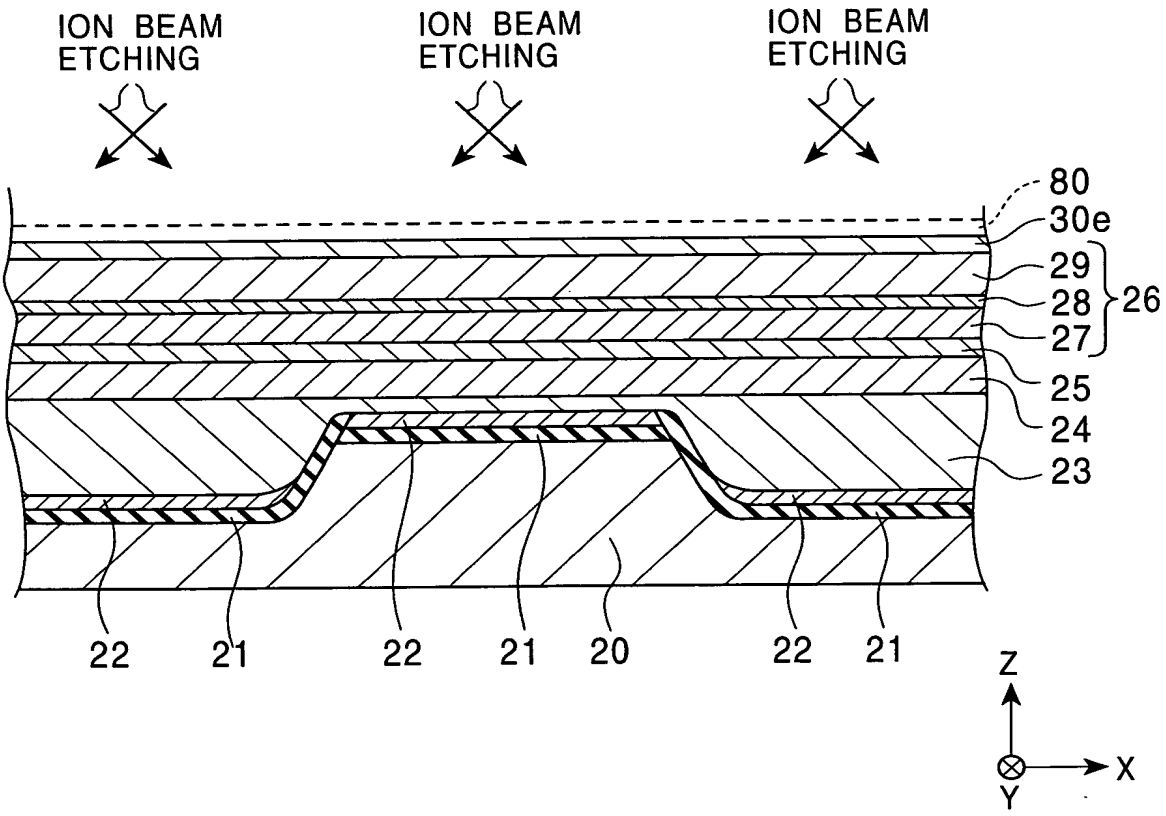
ION BEAM ETCHING
ION BEAM ETCHING
ION BEAM ETCHING
80
30e
29
28
27
26
25
24
23
22
21
22
21
20
22
21
Z
X
Y

FIG. 30

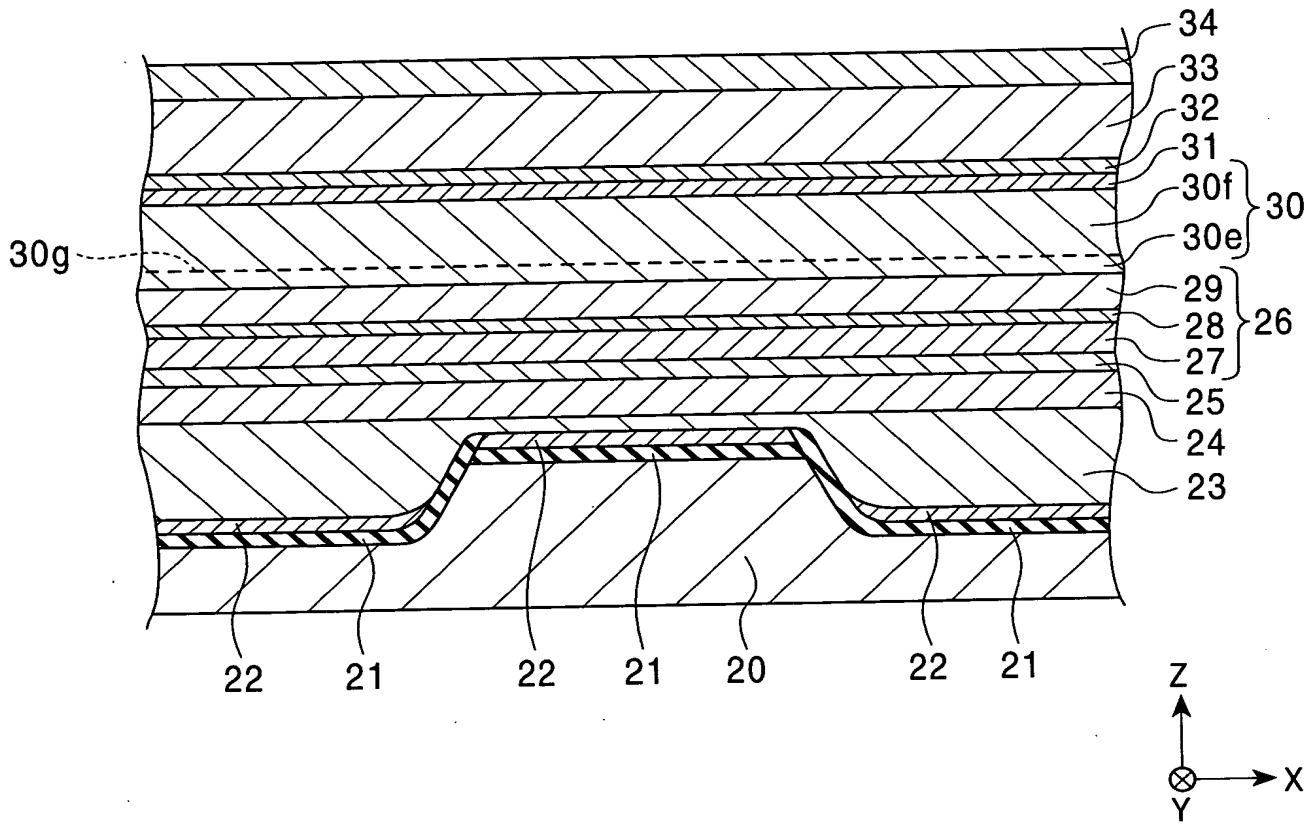
34
33
32
31
30f
30
30e
30g
29
28
26
27
25
24
23
22
21
22
21
20
22
21
Z
X
Y

FIG. 31

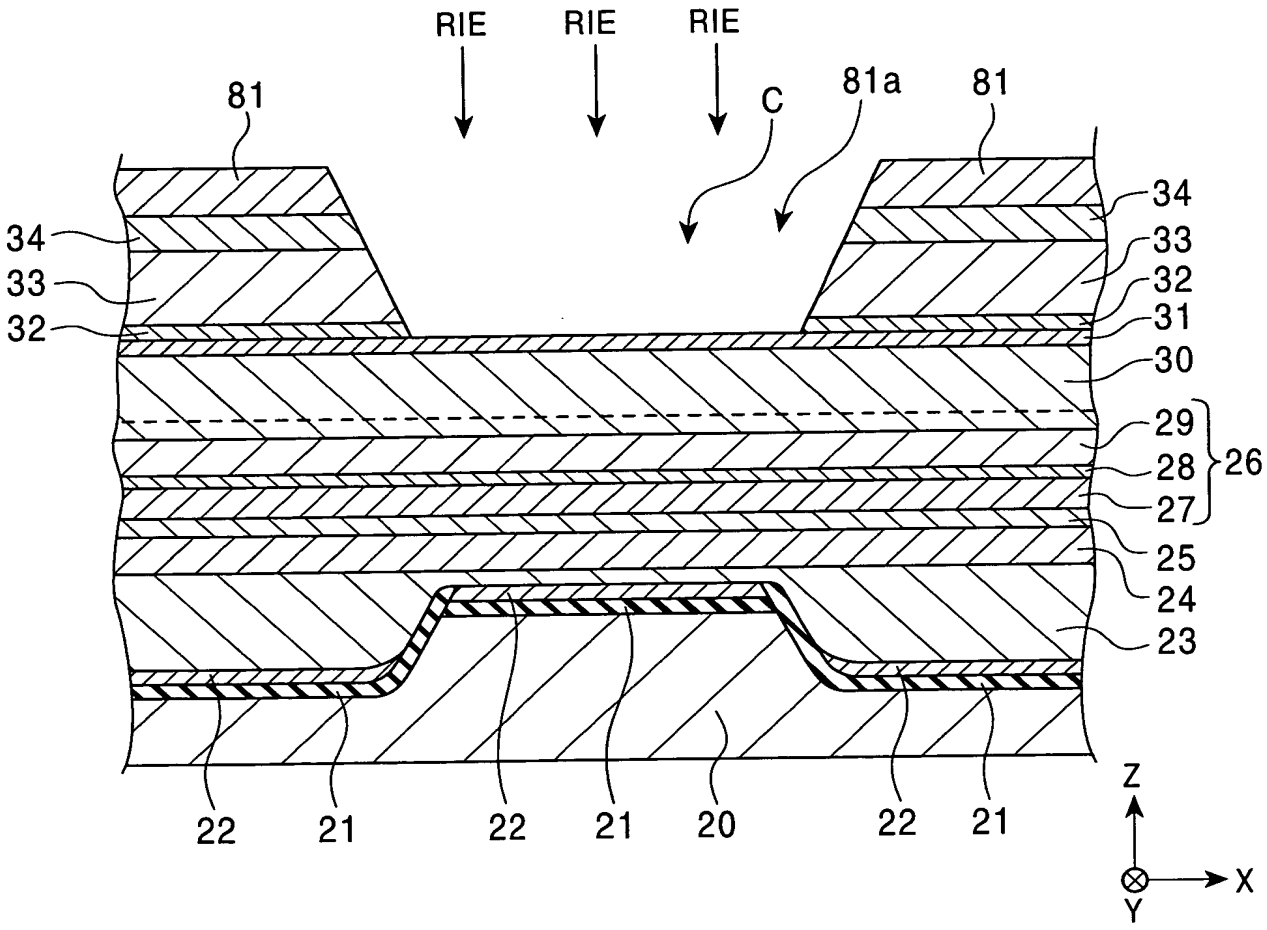
RIE
RIE
RIE
81
C
81a
81
34
33
32
34
33
32
31
30
29
28
27
26
25
24
23
22
21
22
21
20
22
21
Z
X
Y

FIG. 32

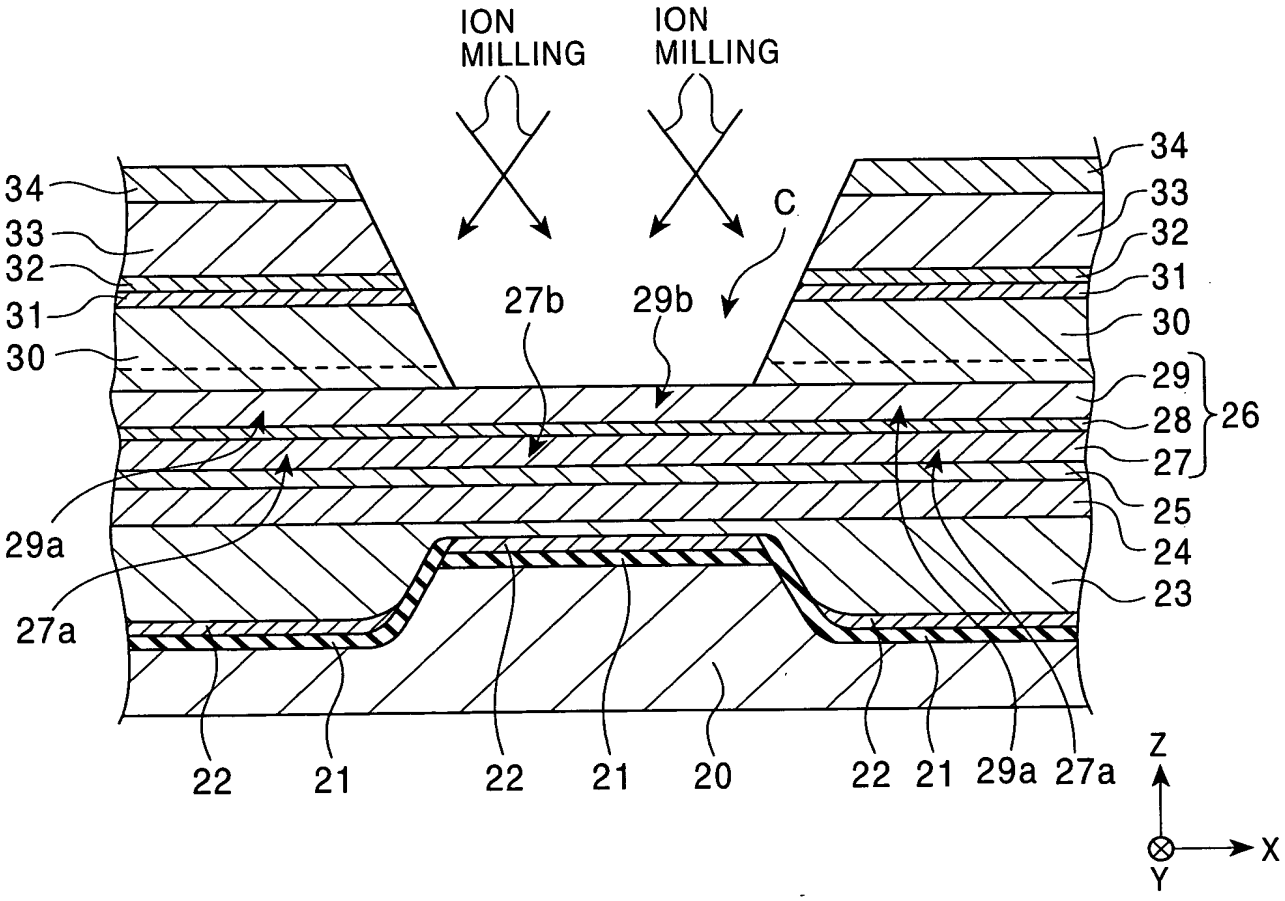
ION MILLING
ION MILLING
C
34
33
32
31
30
27b
29b
29
28
27
26
25
24
23
29a
27a
22
21
22
21
20
22
21
29a
27a
Z
X
Y

FIG. 33

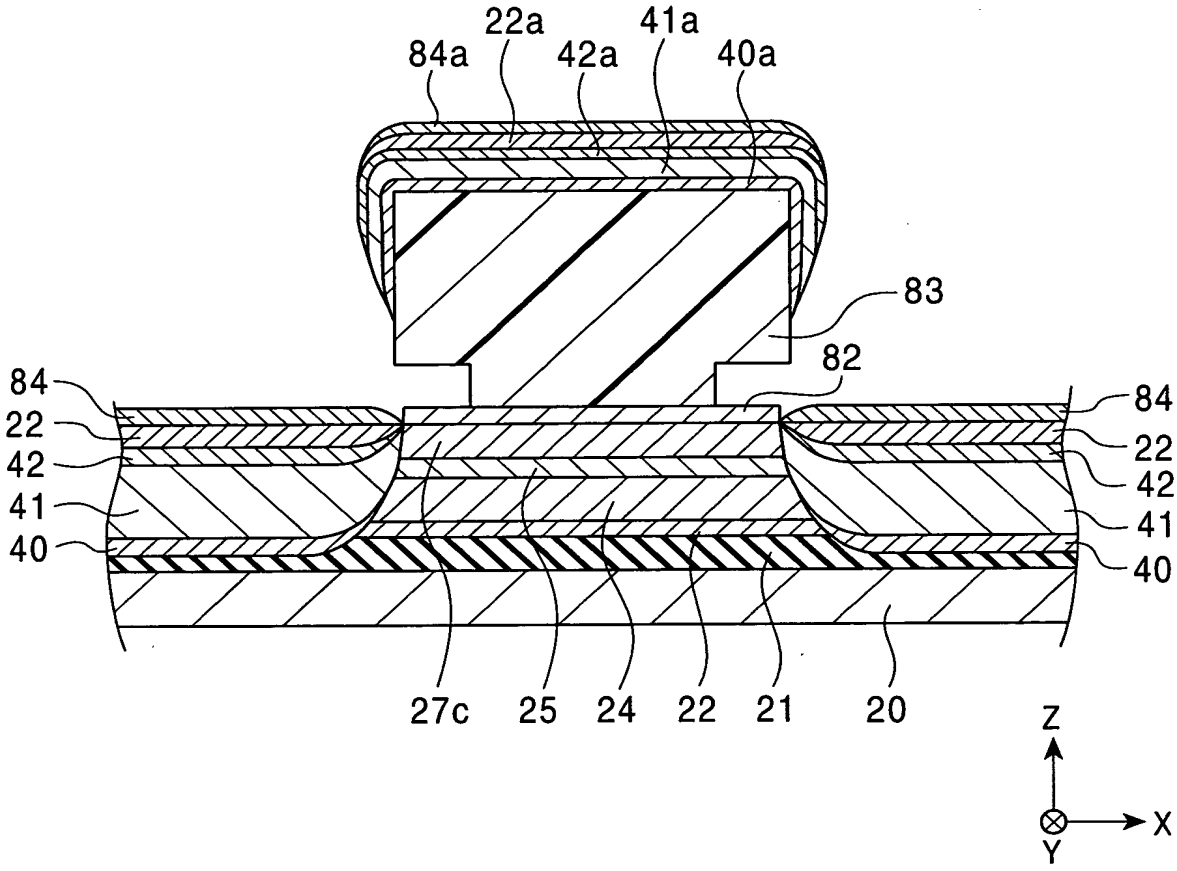
22a
41a
84a
42a
40a
83
82
84
22
42
41
40
84
22
42
41
40
27c
25
24
22
21
20
Z
X
Y

FIG. 34

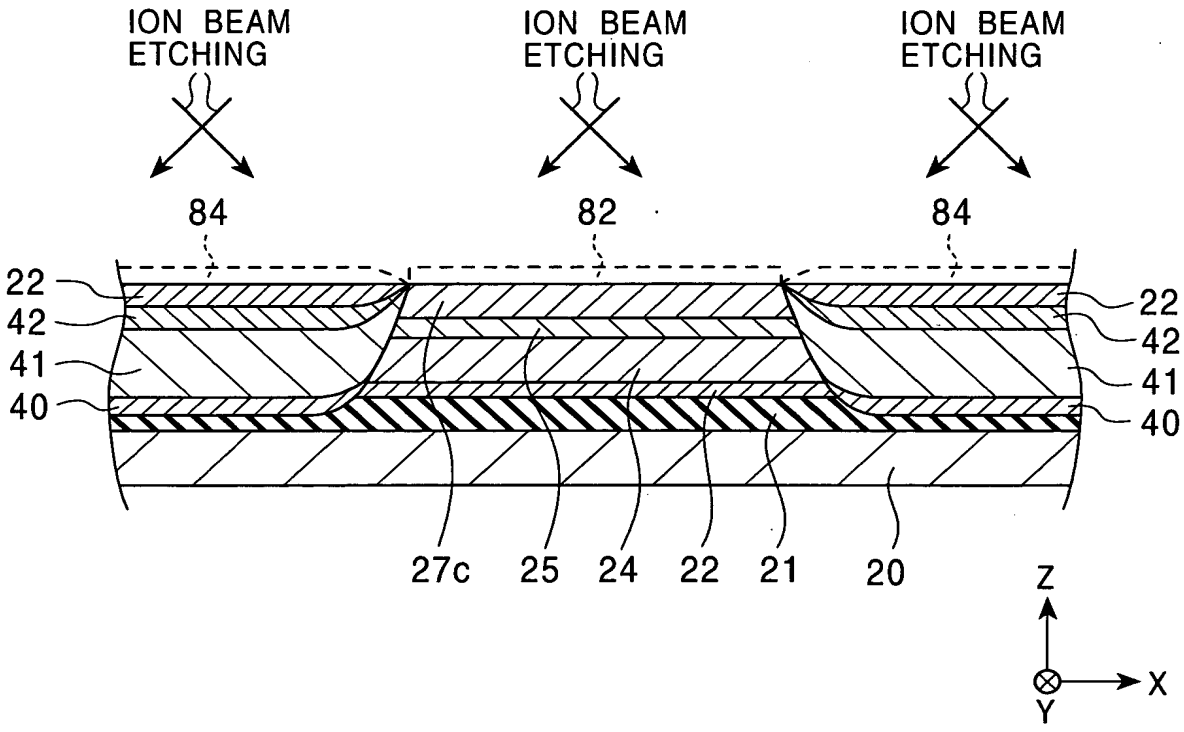
ION BEAM ETCHING
ION BEAM ETCHING
ION BEAM ETCHING
84
82
84
22
42
41
40
22
42
41
40
27c
25
24
22
21
20
Z
X
Y

FIG. 35

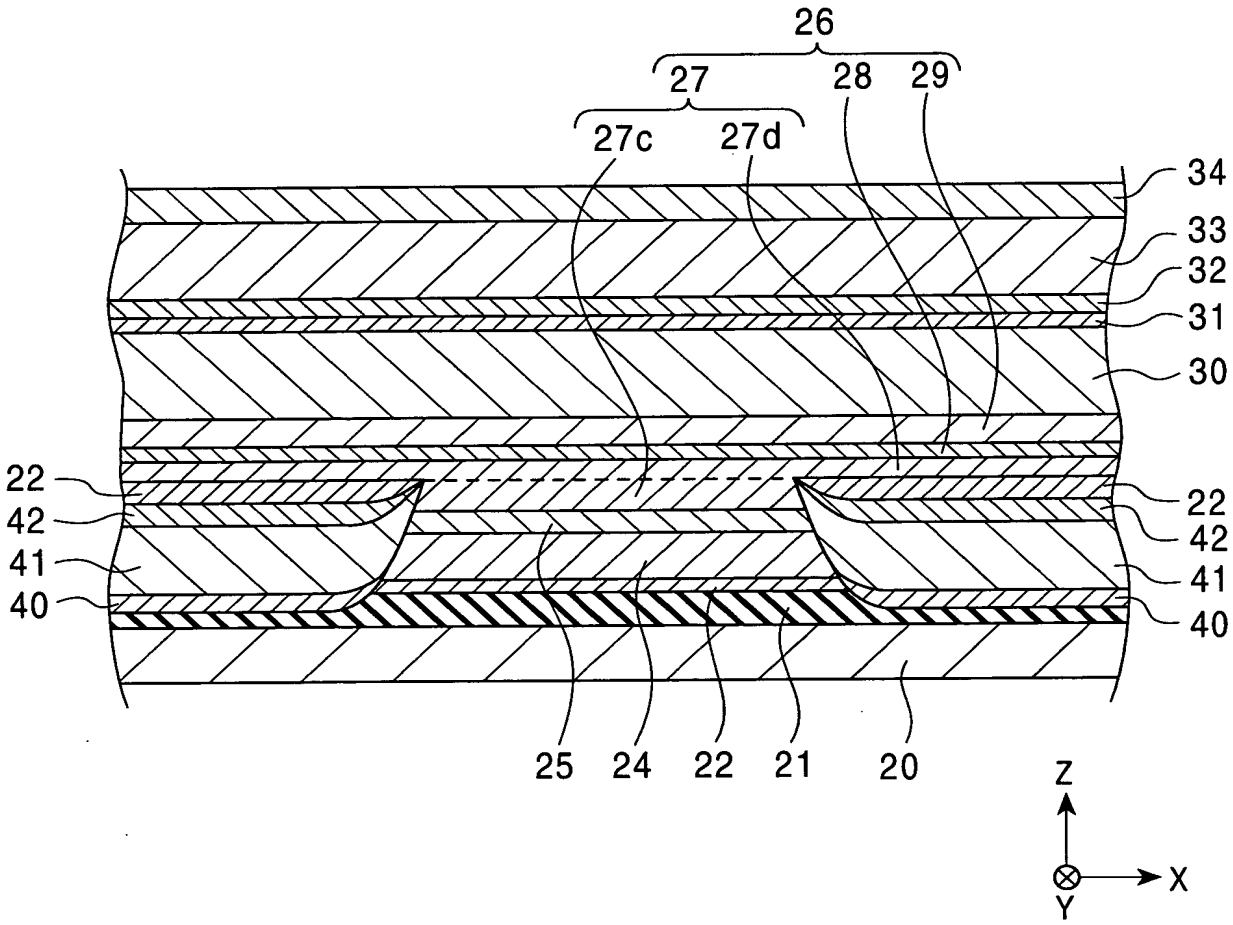
26
27
28
29
27c
27d
34
33
32
31
30
22
42
41
40
22
42
41
40
25
24
22
21
20
Z
X
Y

FIG. 36

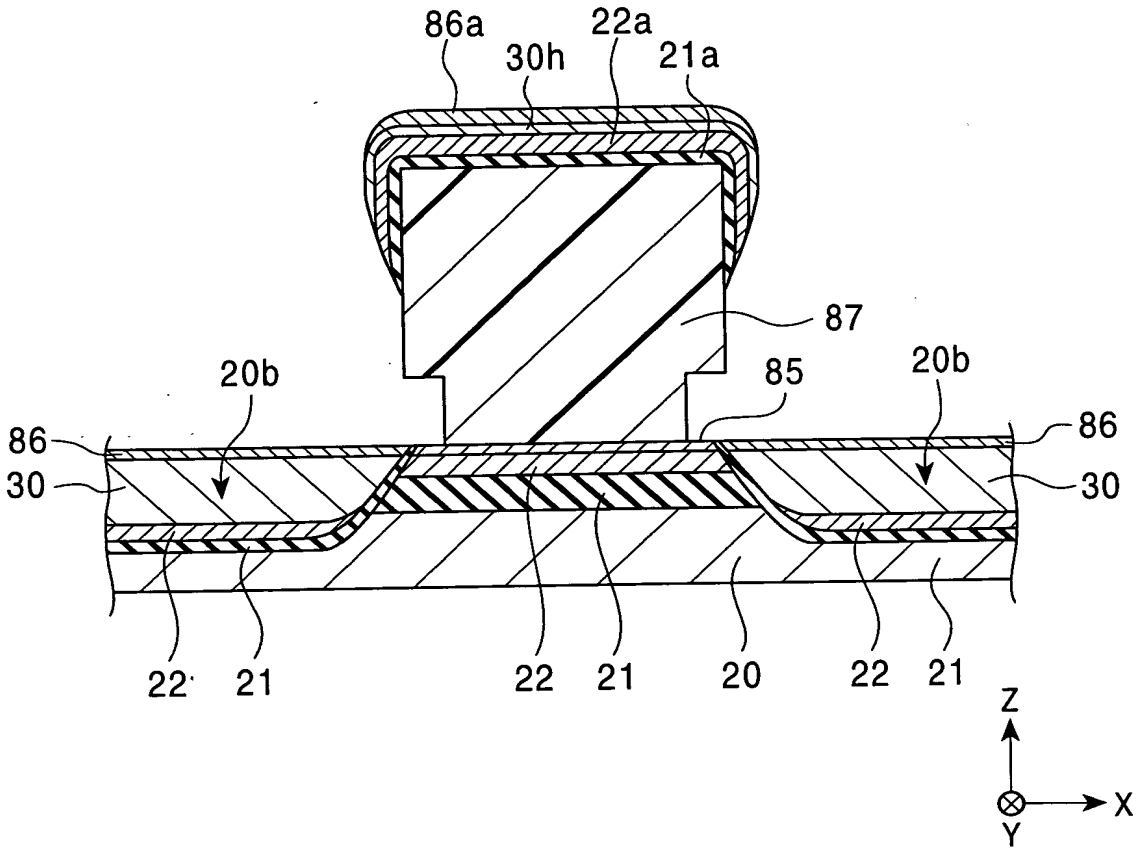

FIG. 37

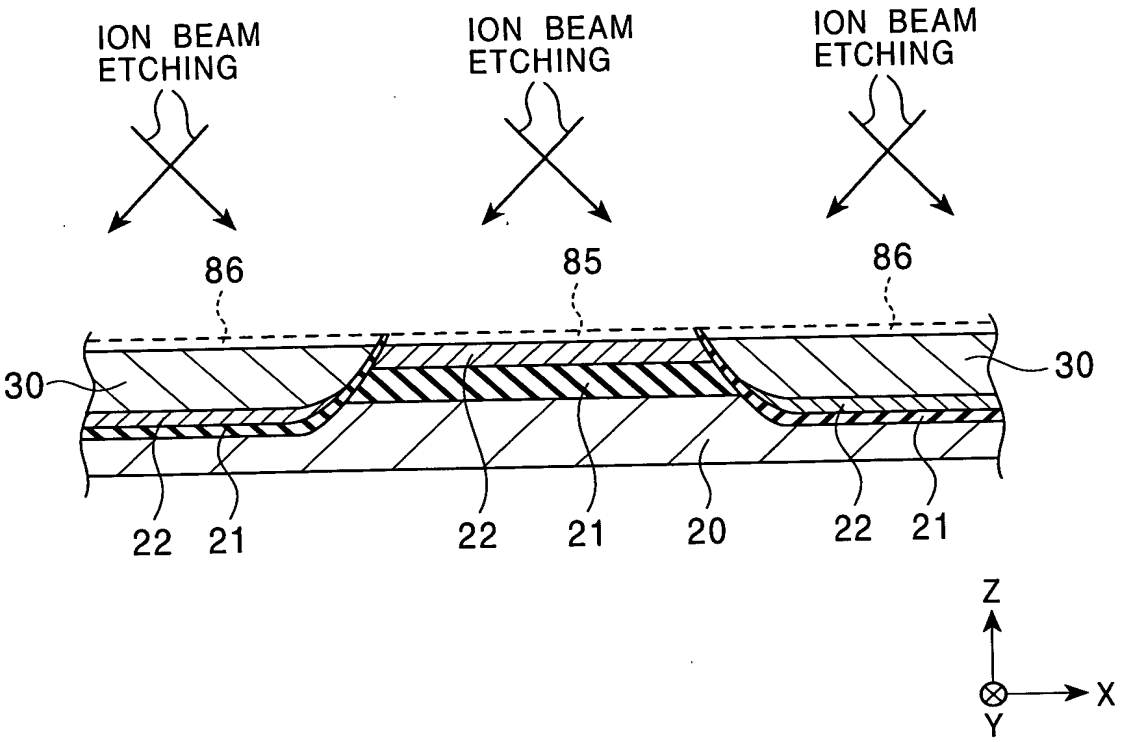
ION BEAM ETCHING
ION BEAM ETCHING
ION BEAM ETCHING
86
85
86
30
30
22
21
22
21
20
22
21
Z
X
Y

FIG. 38

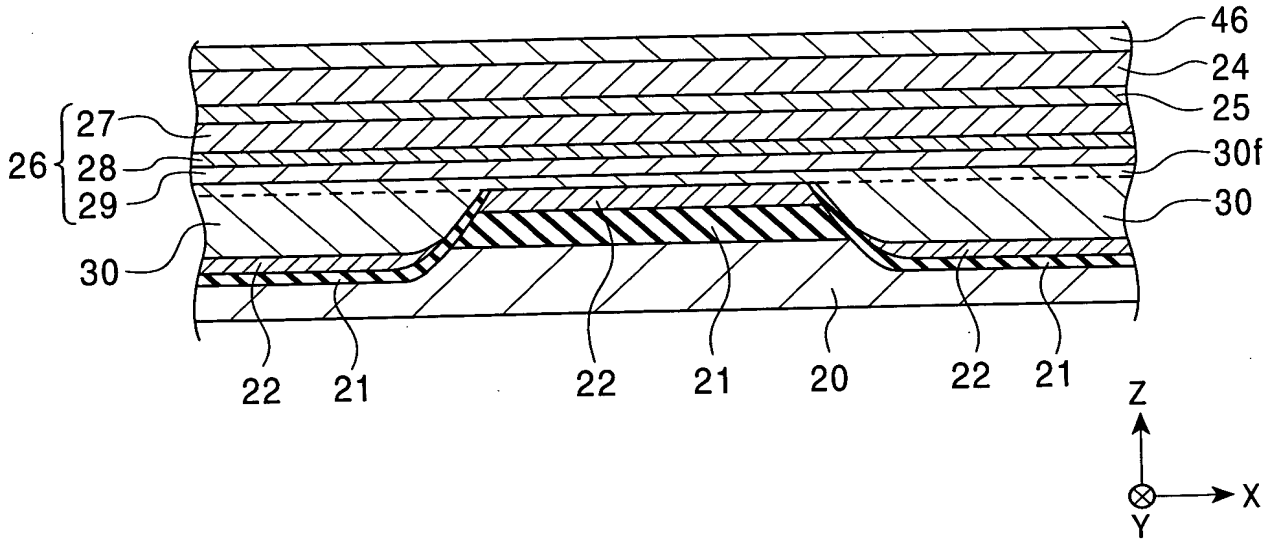

FIG. 39

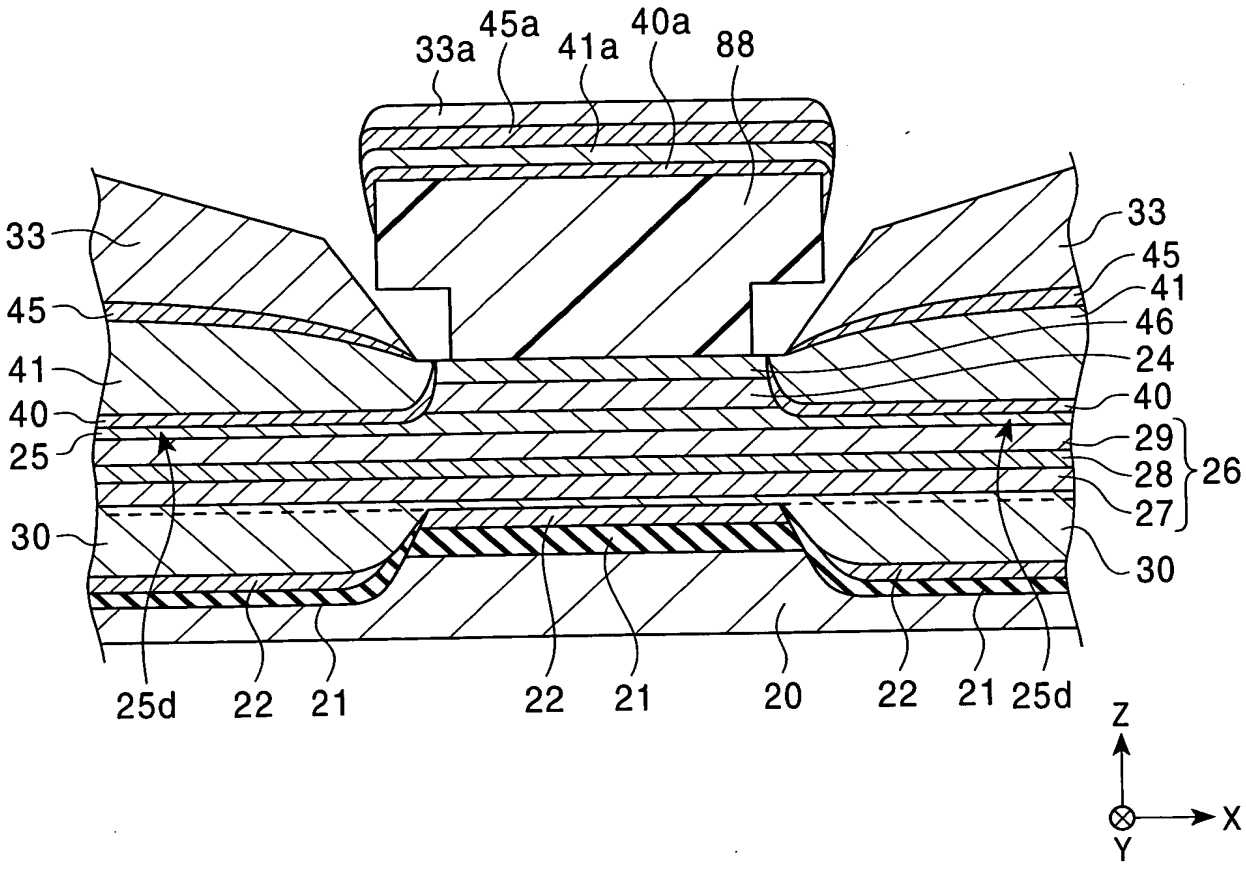
33a
45a
41a
40a
88
33
45
41
40
25
30
33
45
41
46
24
40
29
28
27
26
30
25d
22
21
22
21
20
22
21
25d
Z
X
Y

FIG. 40

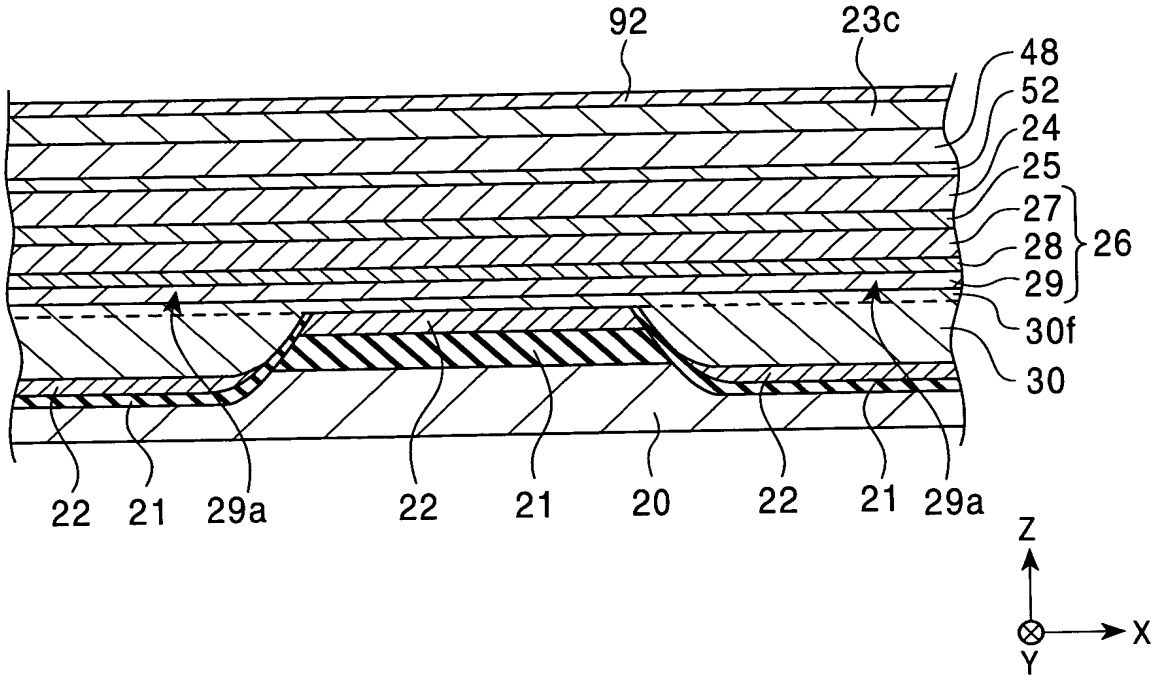

FIG. 41

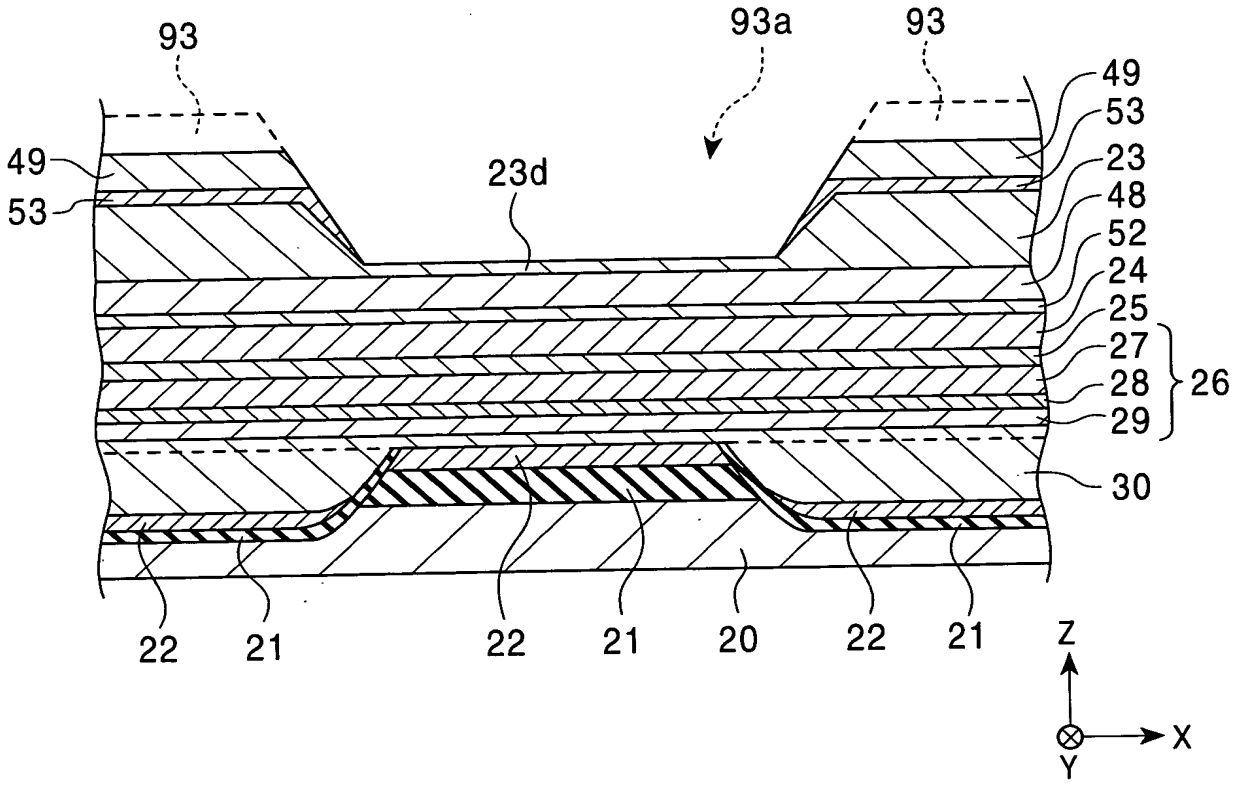
93
93a
93
49
53
23d
49
53
23
48
52
24
25
27
28
29
26
30
22
21
22
21
20
22
21
Z
X
Y

FIG. 42

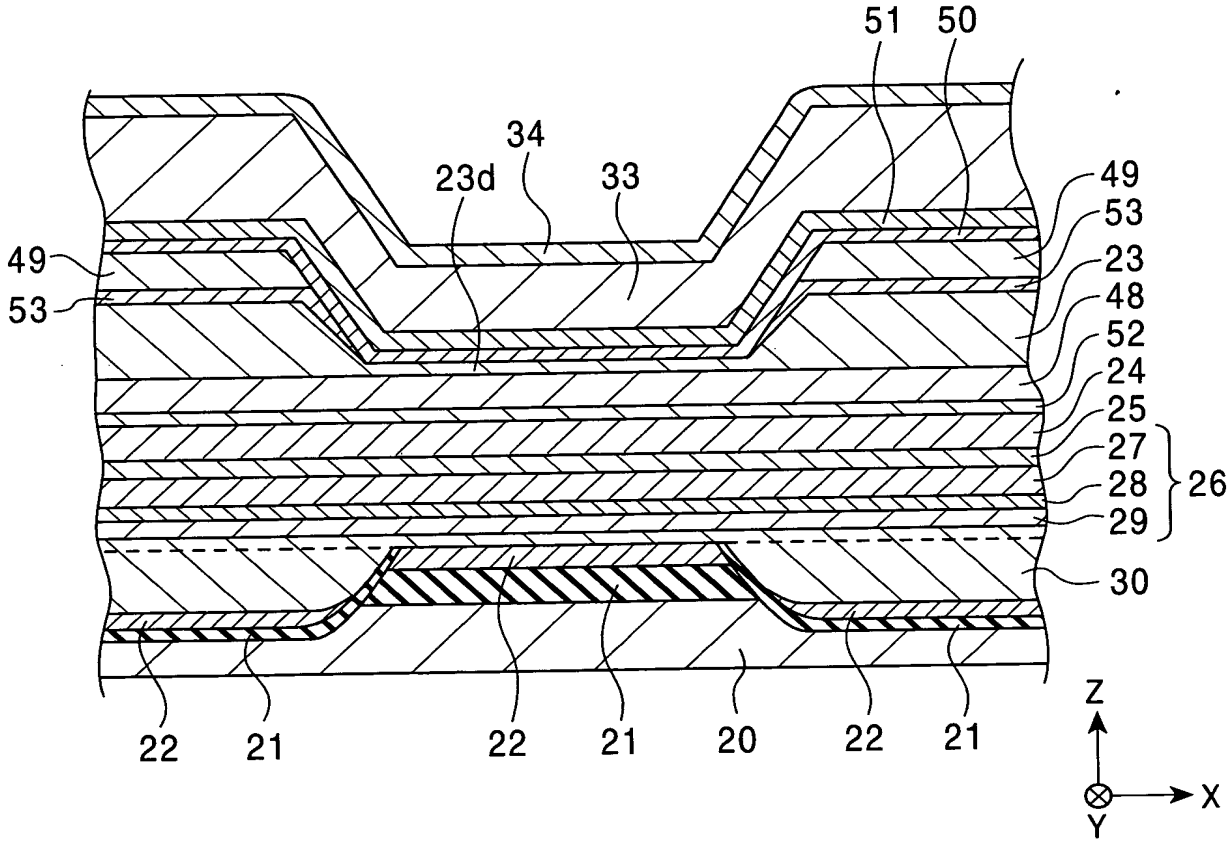
51
50
34
23d
33
49
53
49
53
23
48
52
24
25
27
28
29
26
30
22
21
22
21
20
22
21
Z
X
Y

FIG. 43

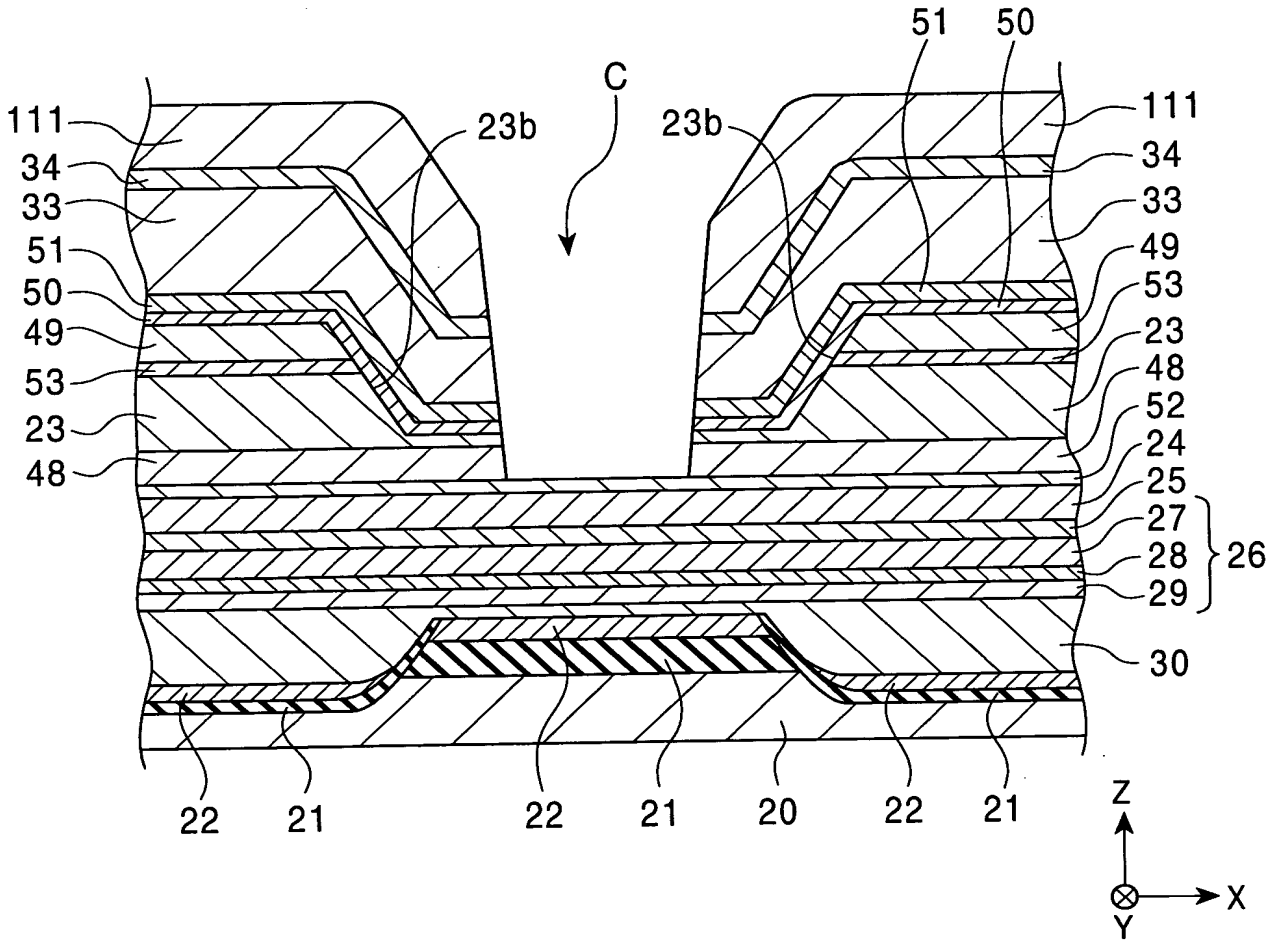
51
50
C
111
23b
23b
111
34
34
33
33
51
49
50
53
49
23
53
48
23
52
48
24
25
27
28
26
29
30
22
21
22
21
20
22
21
Z
X
Y

FIG. 44

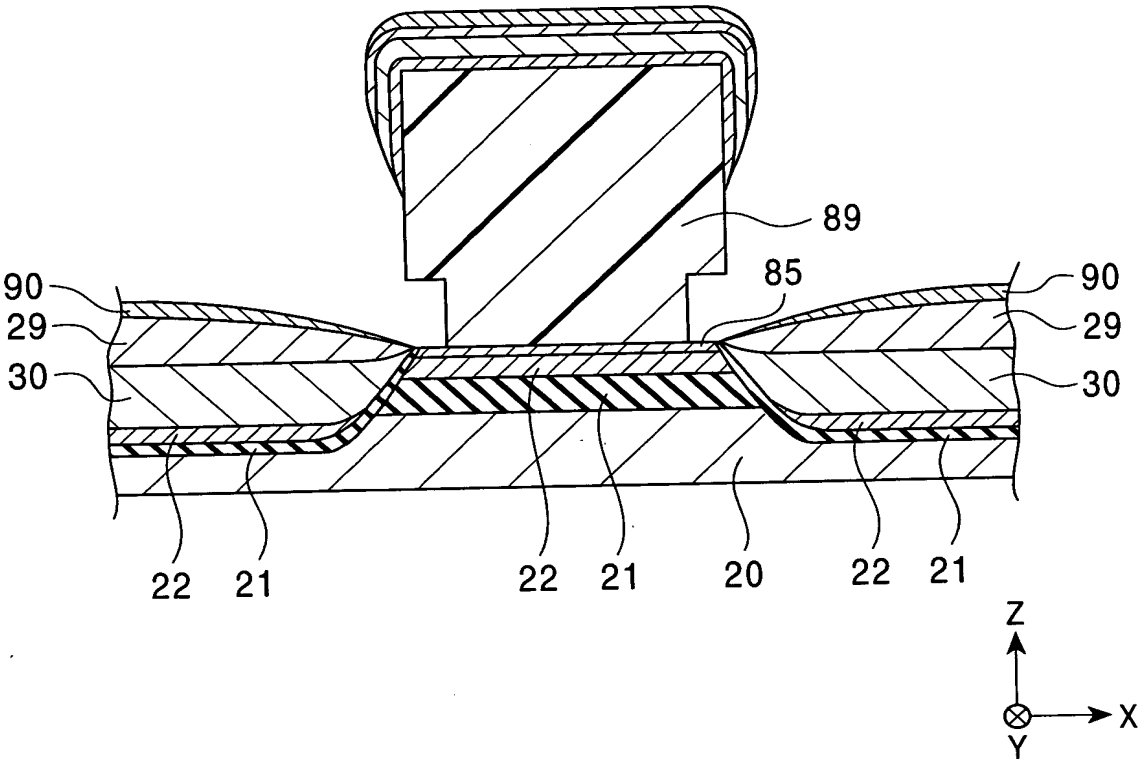

FIG. 45

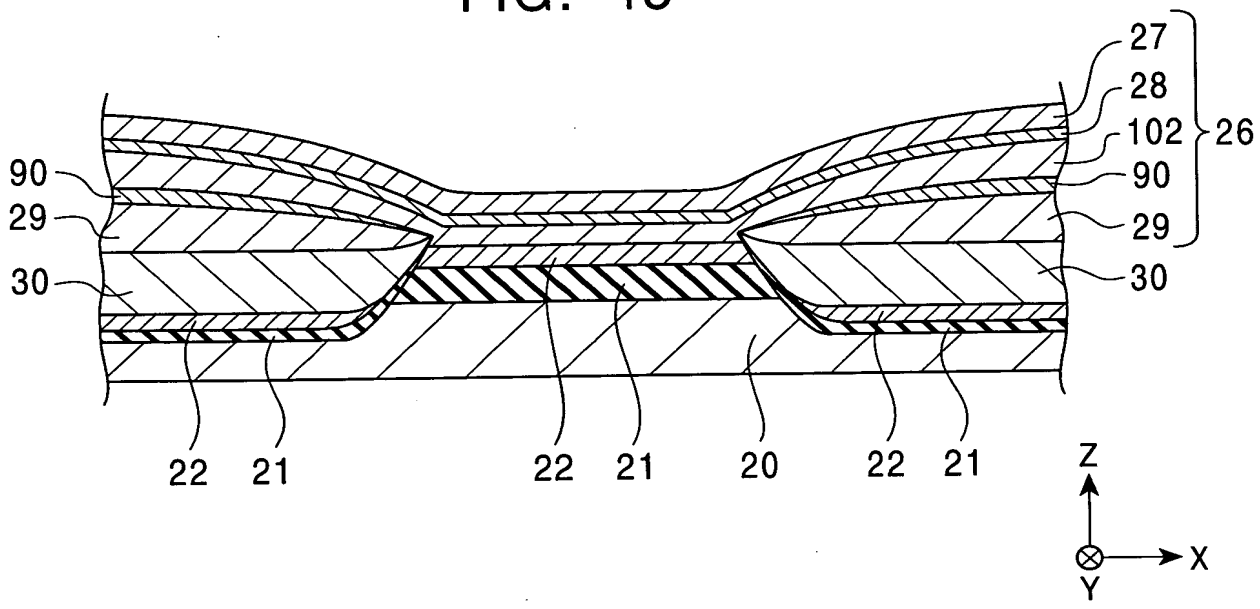

FIG. 46

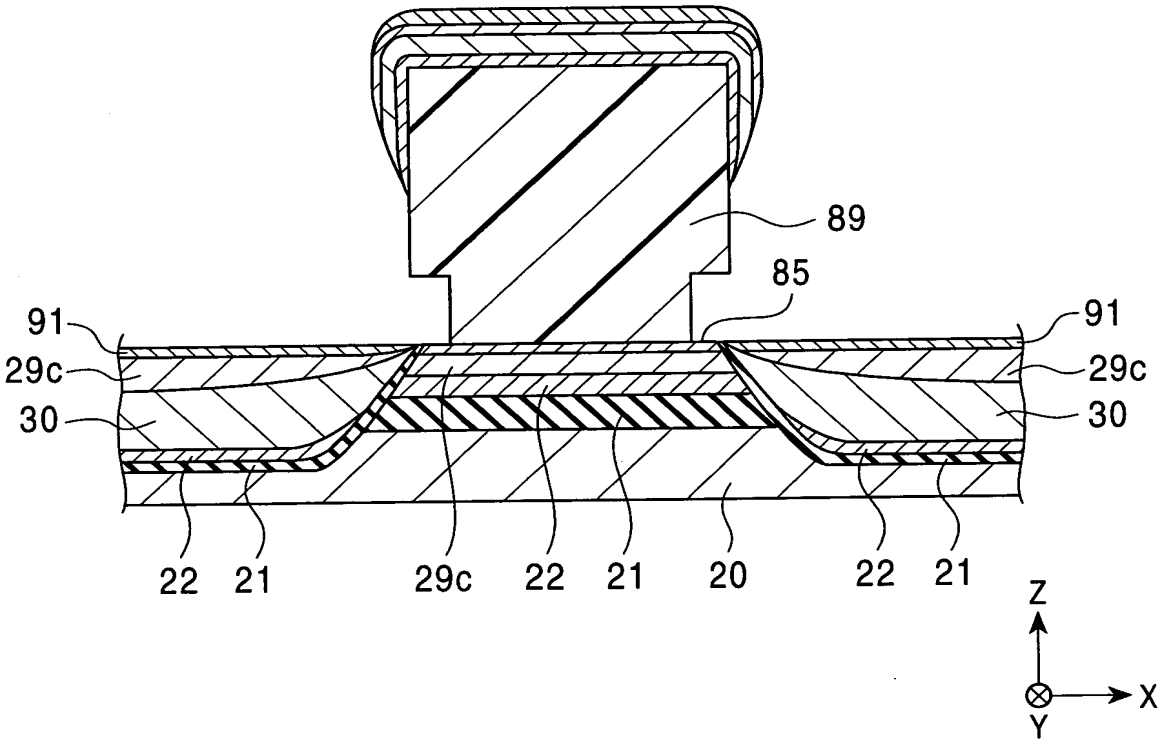

FIG. 47

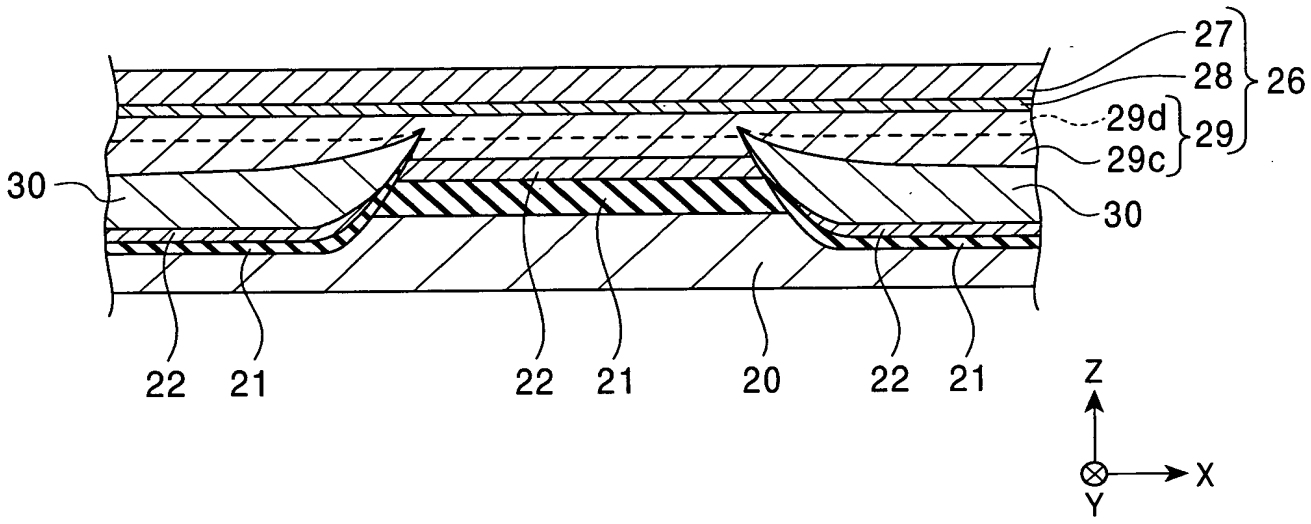

FIG. 48

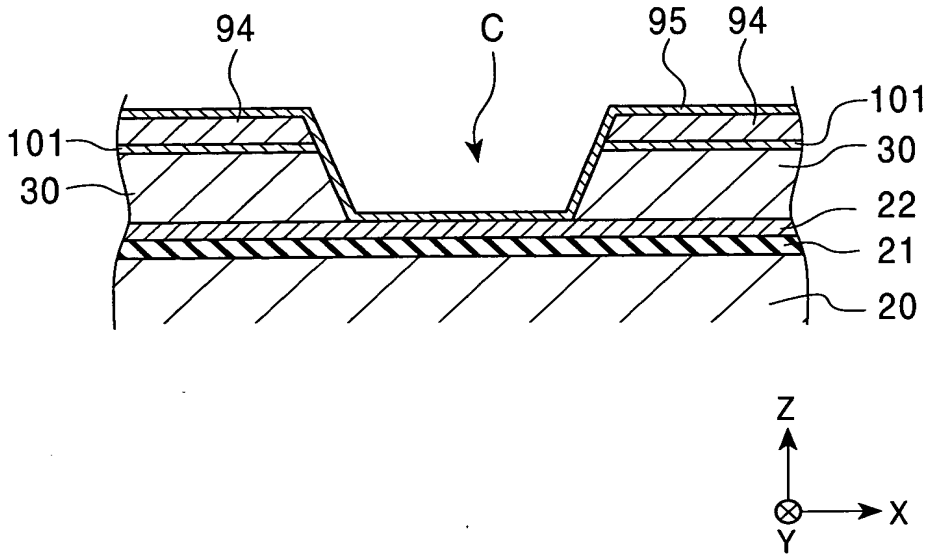

FIG. 49

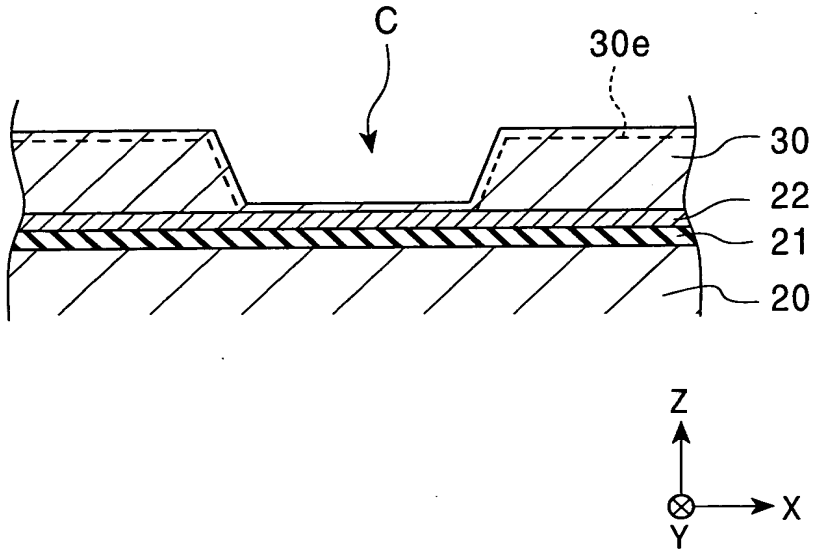

FIG. 50

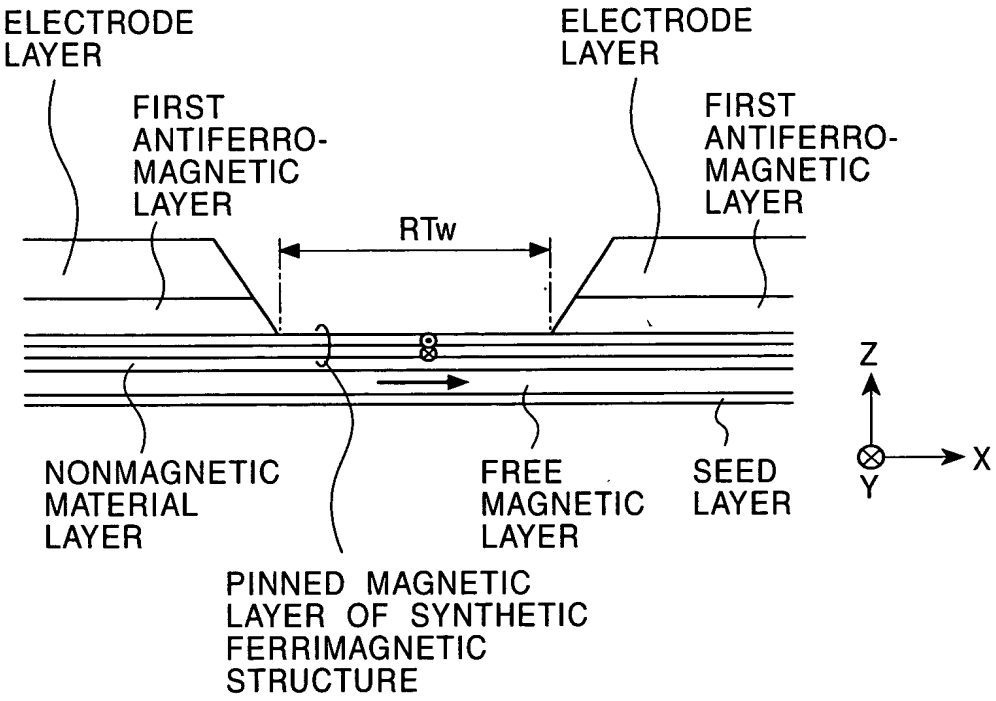
ELECTRODE LAYER
ELECTRODE LAYER
FIRST ANTIFERRO-MAGNETIC LAYER
FIRST ANTIFERRO-MAGNETIC LAYER
RTw
Z
X
Y
NONMAGNETIC MATERIAL LAYER
FREE MAGNETIC LAYER
SEED LAYER
PINNED MAGNETIC LAYER OF SYNTHETIC FERRIMAGNETIC STRUCTURE

FIG. 51

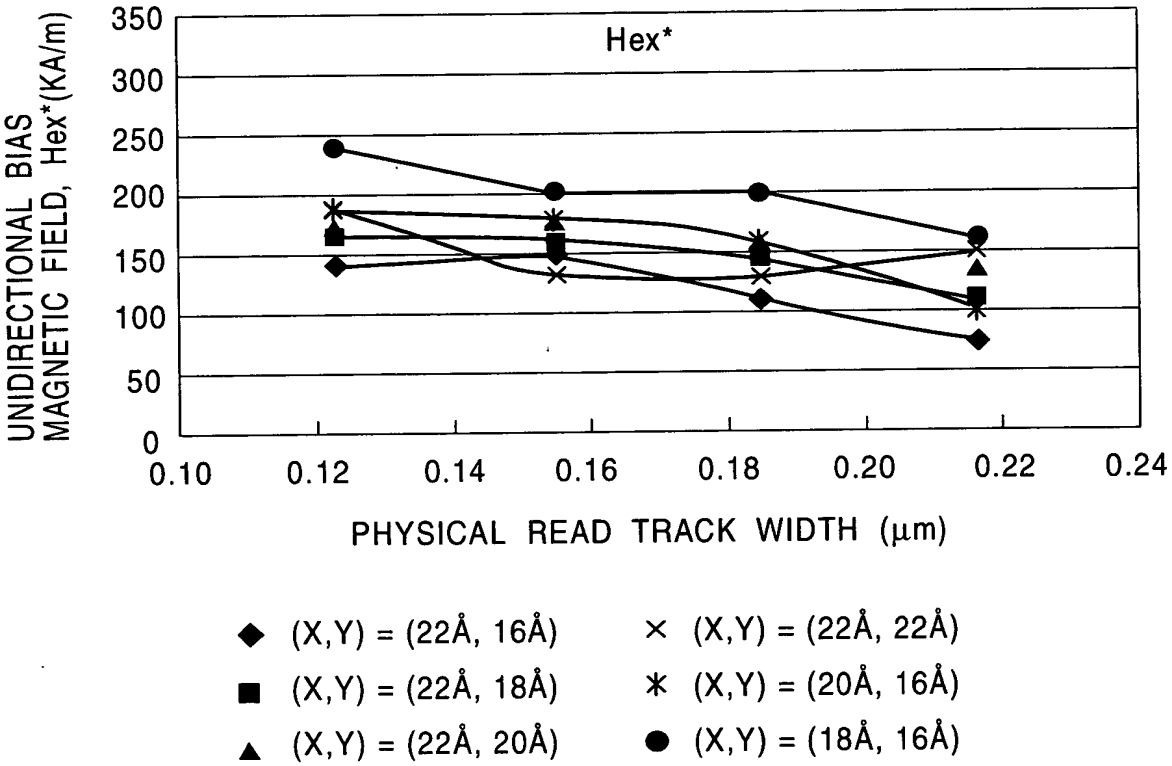
Hex*
UNIDIRECTIONAL BIAS MAGNETIC FIELD, Hex*(KA/m)
350
300
250
200
150
100
50
0
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
PHYSICAL READ TRACK WIDTH (μm)
◆ (X,Y) = (22Å, 16Å)
× (X,Y) = (22Å, 22Å)
■ (X,Y) = (22Å, 18Å)
✳ (X,Y) = (20Å, 16Å)
▲ (X,Y) = (22Å, 20Å)
● (X,Y) = (18Å, 16Å)

FIG. 52

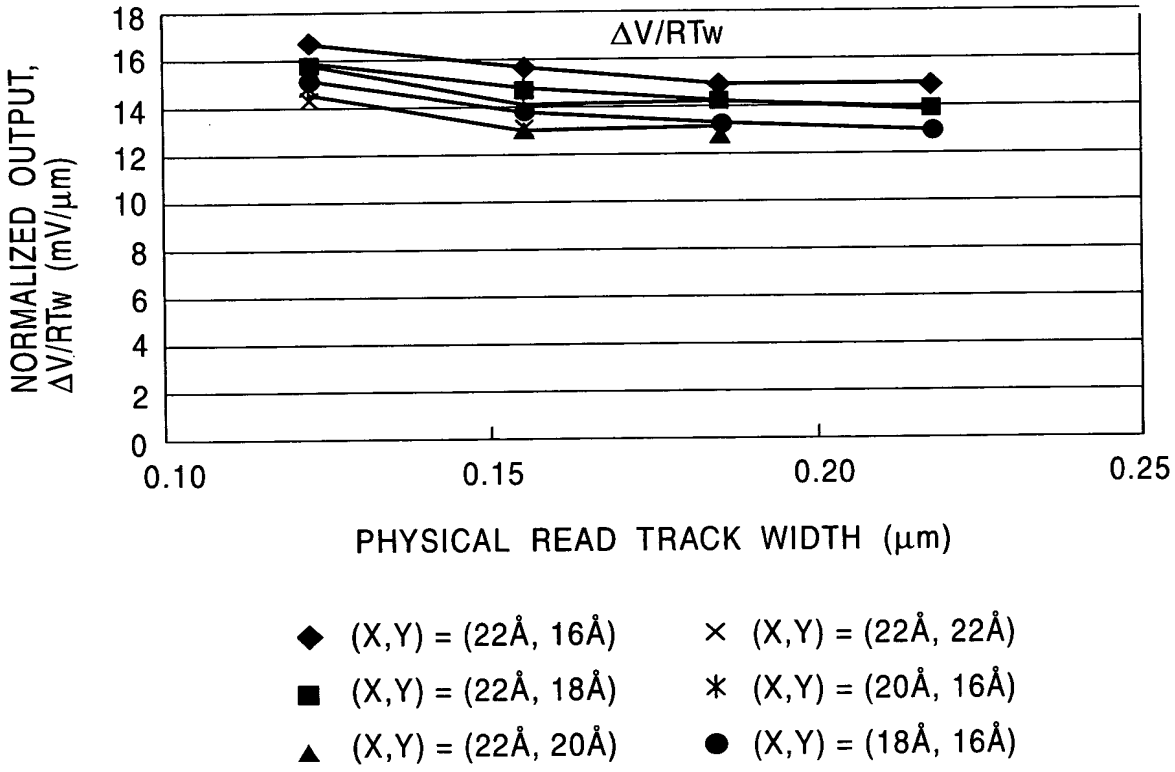
ΔV/RTw
NORMALIZED OUTPUT, ΔV/RTw (mV/μm)
18
16
14
12
10
8
6
4
2
0
0.10
0.15
0.20
0.25
PHYSICAL READ TRACK WIDTH (μm)
◆ (X,Y) = (22Å, 16Å)
■ (X,Y) = (22Å, 18Å)
▲ (X,Y) = (22Å, 20Å)
× (X,Y) = (22Å, 22Å)
∗ (X,Y) = (20Å, 16Å)
● (X,Y) = (18Å, 16Å)

FIG. 53

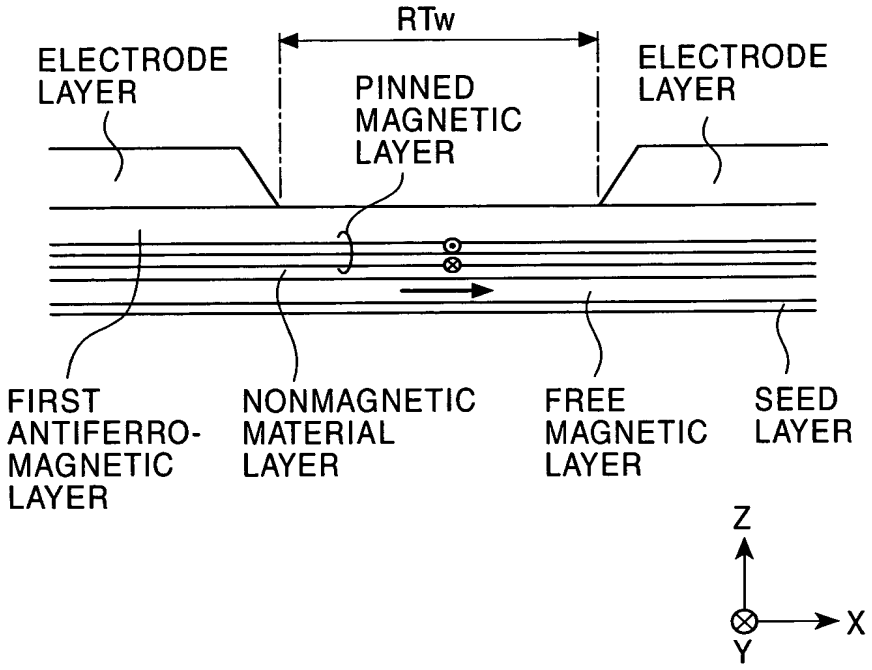
RTw
ELECTRODE LAYER
PINNED MAGNETIC LAYER
ELECTRODE LAYER
FIRST ANTIFERRO-MAGNETIC LAYER
NONMAGNETIC MATERIAL LAYER
FREE MAGNETIC LAYER
SEED LAYER
Z
X
Y

FIG. 54

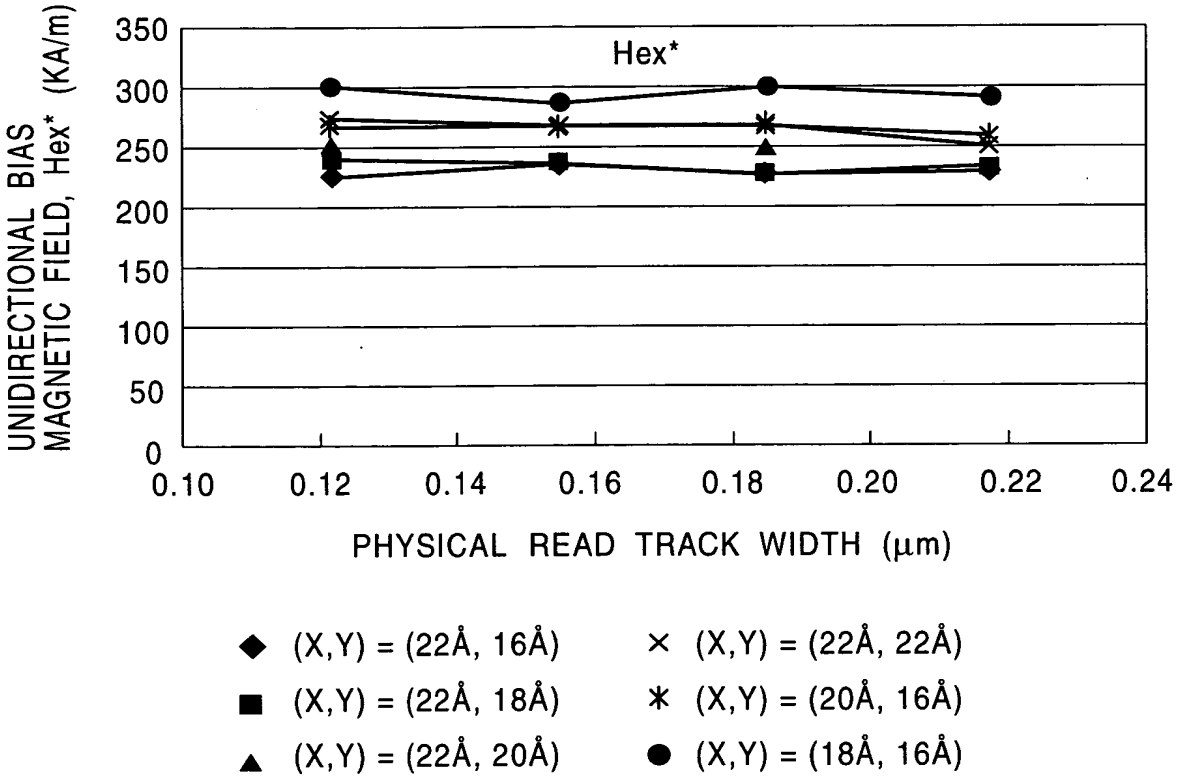
Hex*
UNIDIRECTIONAL BIAS MAGNETIC FIELD, Hex* (KA/m)
350
300
250
200
150
100
50
0
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
PHYSICAL READ TRACK WIDTH (μm)
◆ (X,Y) = (22Å, 16Å)
× (X,Y) = (22Å, 22Å)
■ (X,Y) = (22Å, 18Å)
✱ (X,Y) = (20Å, 16Å)
▲ (X,Y) = (22Å, 20Å)
● (X,Y) = (18Å, 16Å)

FIG. 55

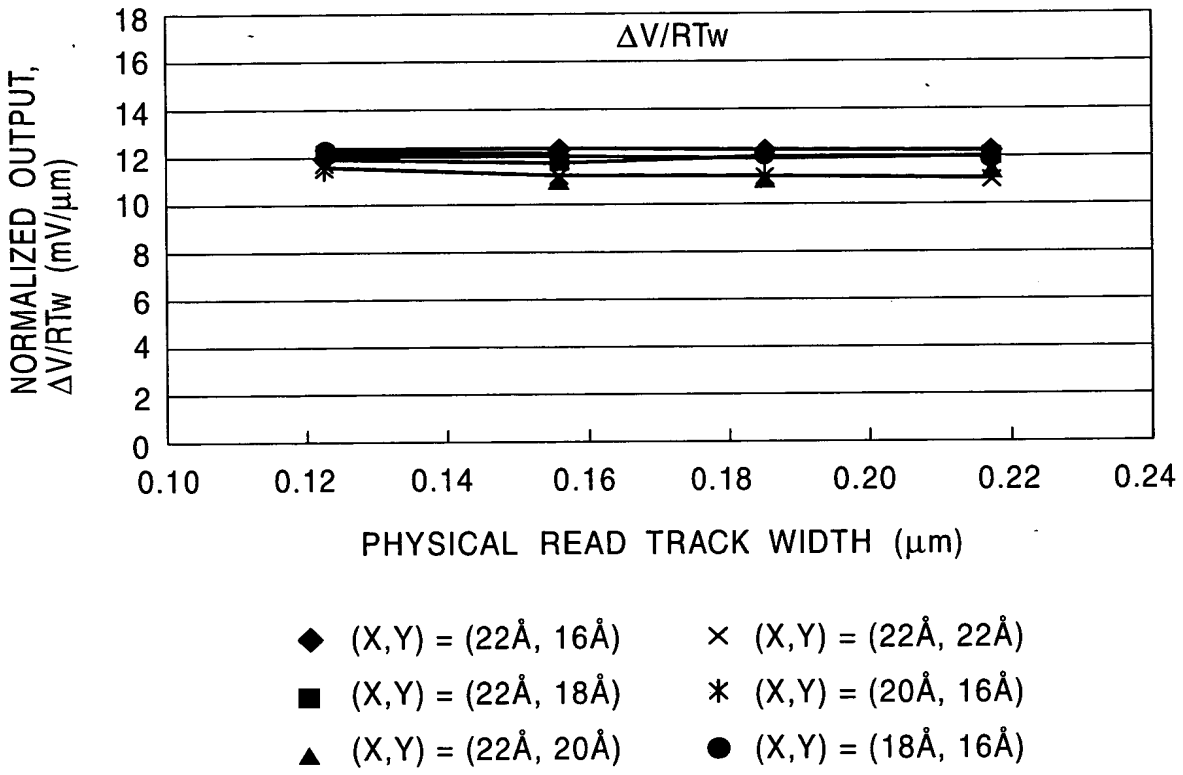
ΔV/RTw
NORMALIZED OUTPUT, ΔV/RTw (mV/μm)
18
16
14
12
10
8
6
4
2
0
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
PHYSICAL READ TRACK WIDTH (μm)
◆ (X,Y) = (22Å, 16Å)
■ (X,Y) = (22Å, 18Å)
▲ (X,Y) = (22Å, 20Å)
× (X,Y) = (22Å, 22Å)
✱ (X,Y) = (20Å, 16Å)
● (X,Y) = (18Å, 16Å)

FIG. 56

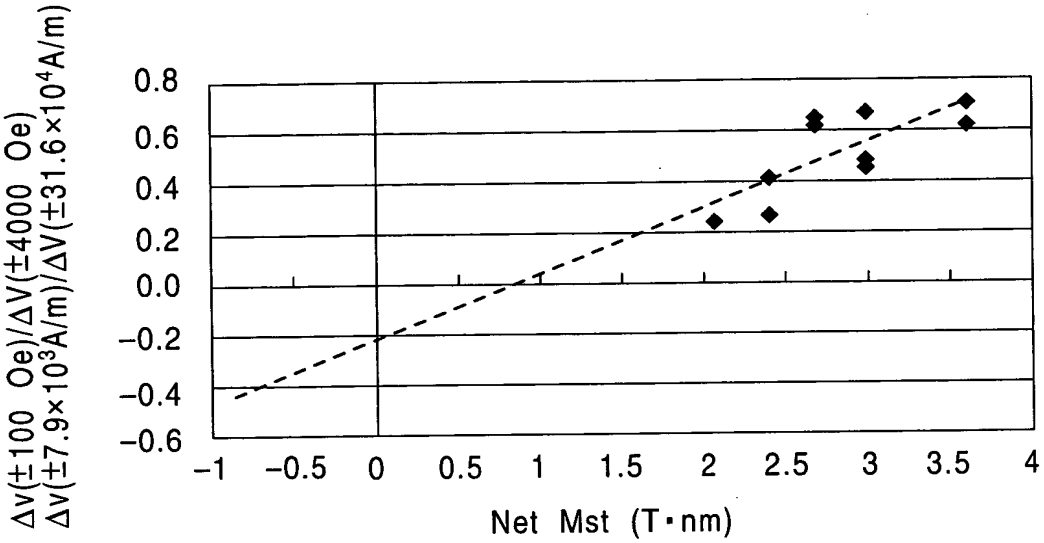
Δv(±100 Oe)/ΔV(±4000 Oe)
Δv(±7.9×10³A/m)/ΔV(±31.6×10⁴A/m)
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−1
−0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
Net Mst (T·nm)

FIG. 57

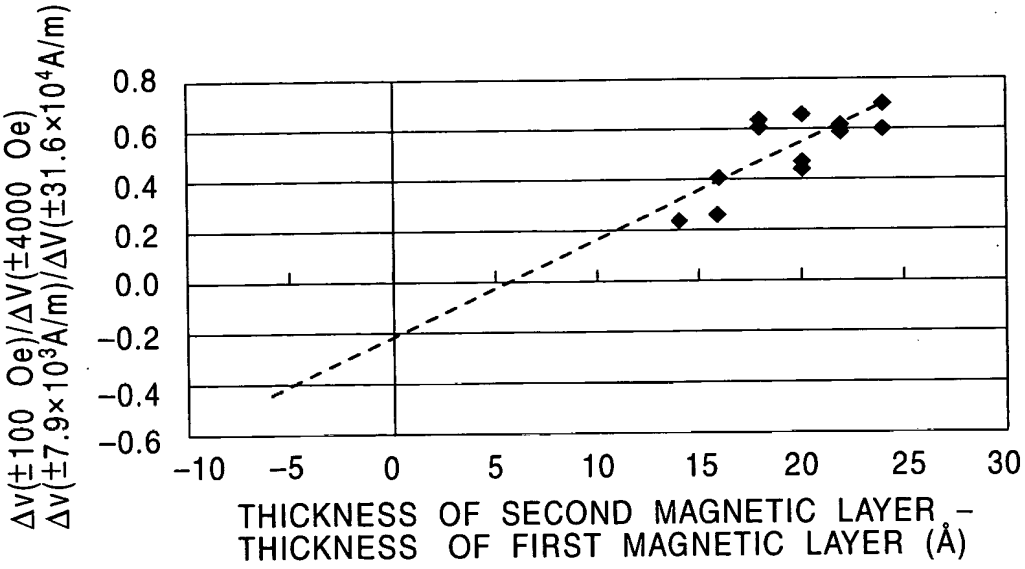
Δv(±100 Oe)/ΔV(±4000 Oe)
Δv(±7.9×10³A/m)/ΔV(±31.6×10⁴A/m)
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−10
−5
0
5
10
15
20
25
30
THICKNESS OF SECOND MAGNETIC LAYER −
THICKNESS OF FIRST MAGNETIC LAYER (Å)

FIG. 58

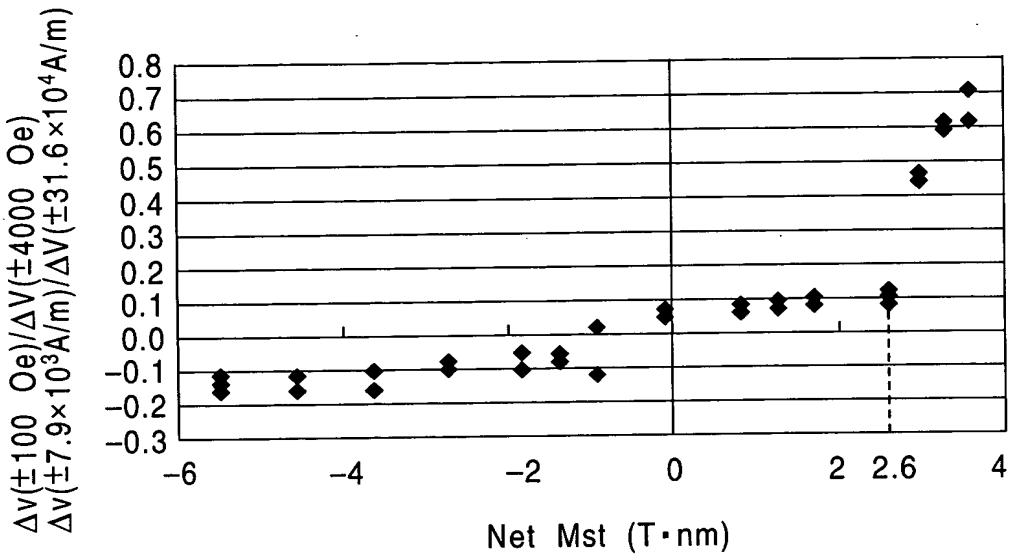
Δv(±100 Oe)/ΔV(±4000 Oe)
Δv(±7.9×10³A/m)/ΔV(±31.6×10⁴A/m)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−6
−4
−2
0
2
2.6
4
Net Mst (T·nm)

FIG. 59

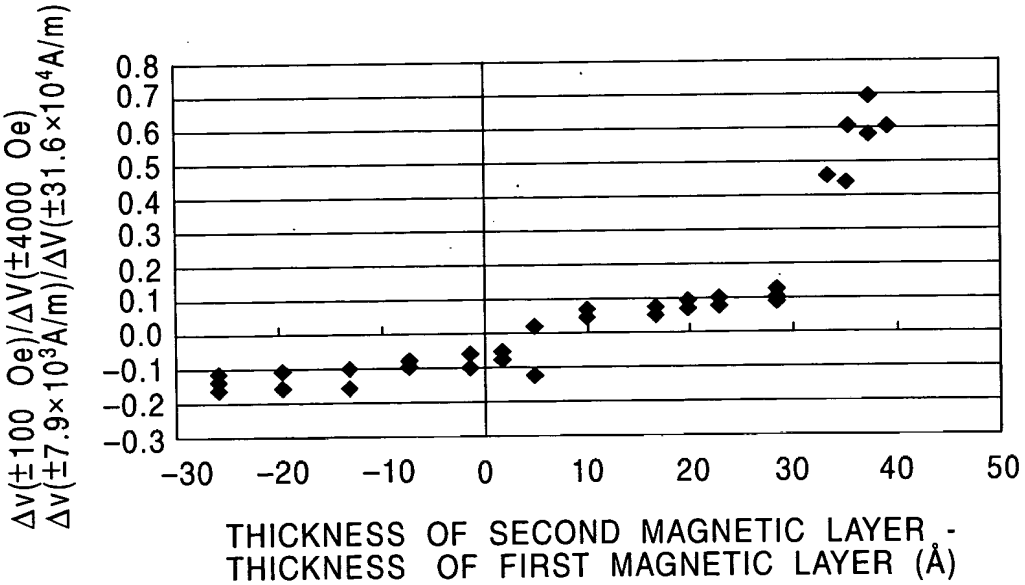
Δv(±100 Oe)/ΔV(±4000 Oe)
Δv(±7.9×10³A/m)/ΔV(±31.6×10⁴A/m)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−30
−20
−10
0
10
20
30
40
50
THICKNESS OF SECOND MAGNETIC LAYER - THICKNESS OF FIRST MAGNETIC LAYER (Å)

FIG. 60

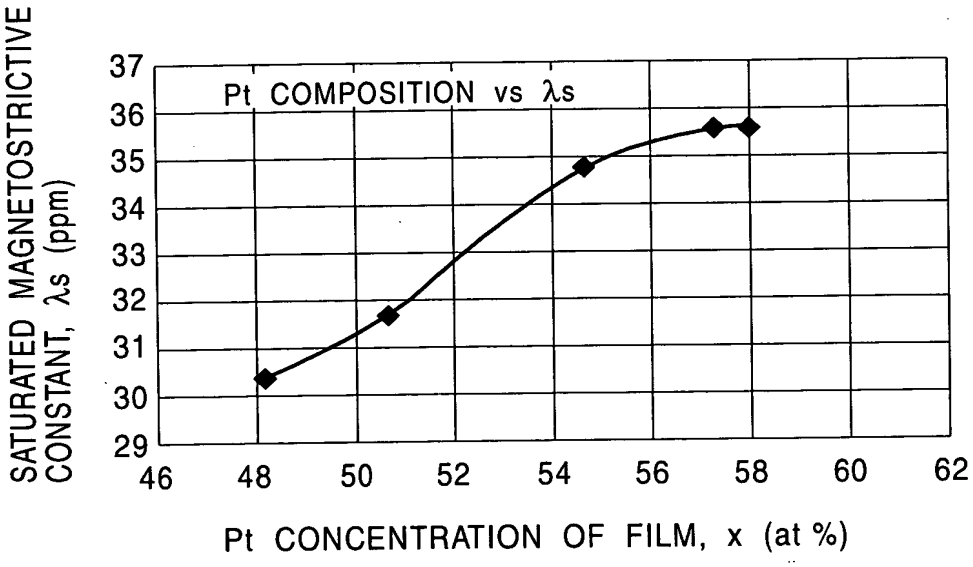
Pt COMPOSITION vs λs
SATURATED MAGNETOSTRICTIVE CONSTANT, λs (ppm)
37
36
35
34
33
32
31
30
29
46
48
50
52
54
56
58
60
62
Pt CONCENTRATION OF FILM, x (at %)

FIG. 61

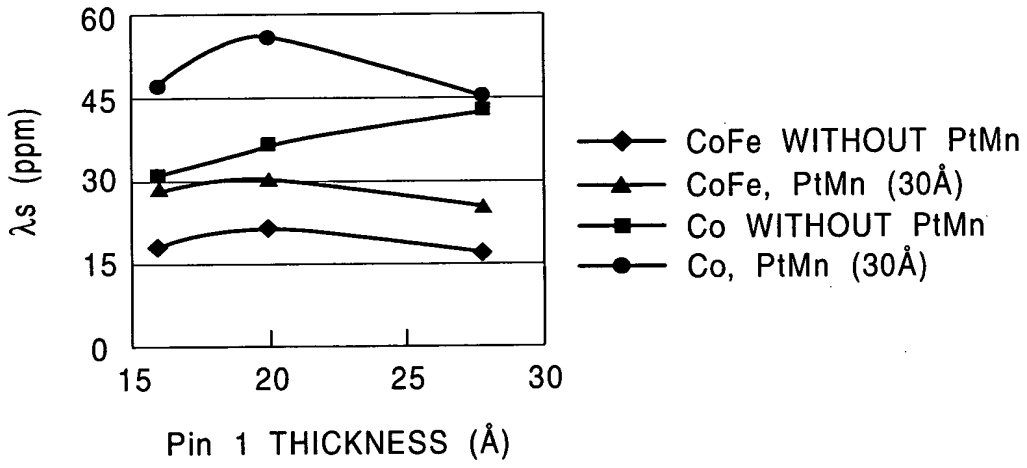
60
45
30
15
0
λs (ppm)
15
20
25
30
Pin 1 THICKNESS (Å)
CoFe WITHOUT PtMn
CoFe, PtMn (30Å)
Co WITHOUT PtMn
Co, PtMn (30Å)

FIG. 62

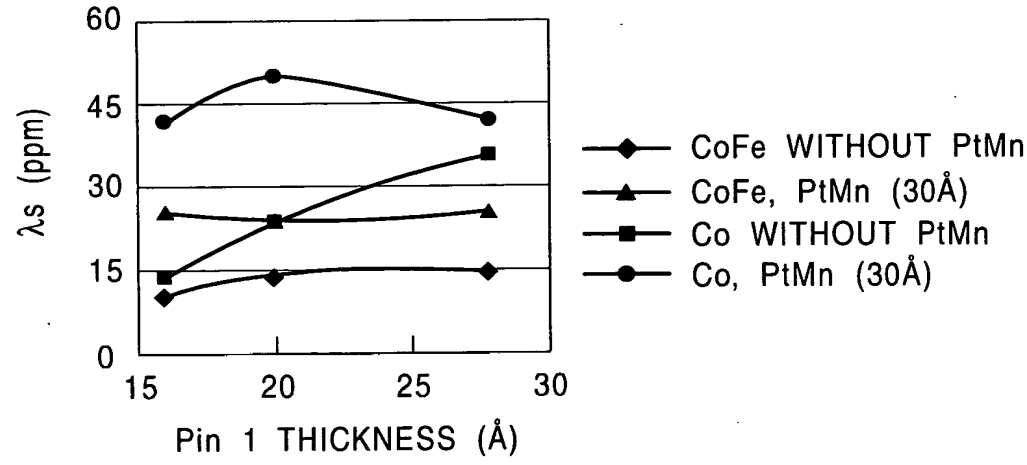
60
45
30
15
0
λs (ppm)
15
20
25
30
Pin 1 THICKNESS (Å)
CoFe WITHOUT PtMn
CoFe, PtMn (30Å)
Co WITHOUT PtMn
Co, PtMn (30Å)

FIG. 63
PRIOR ART

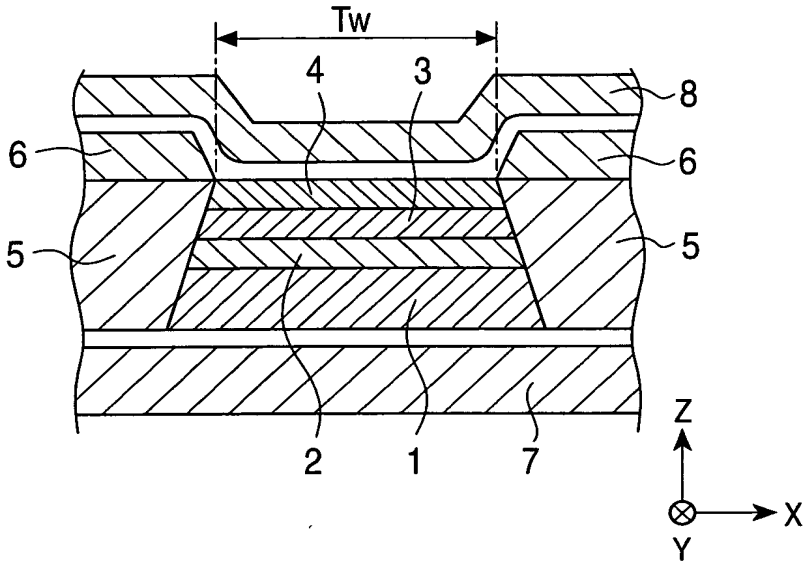

FIG. 64
PRIOR ART

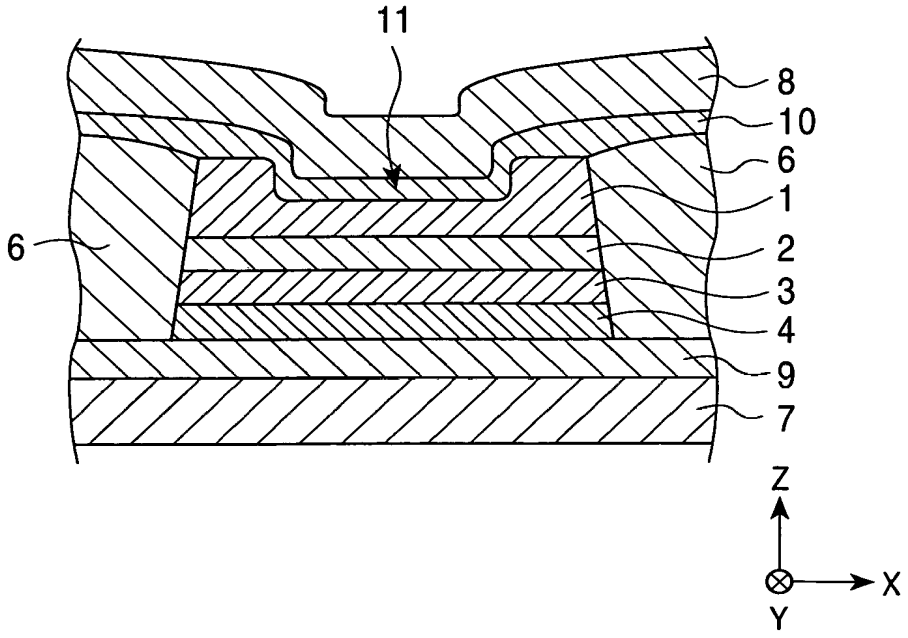
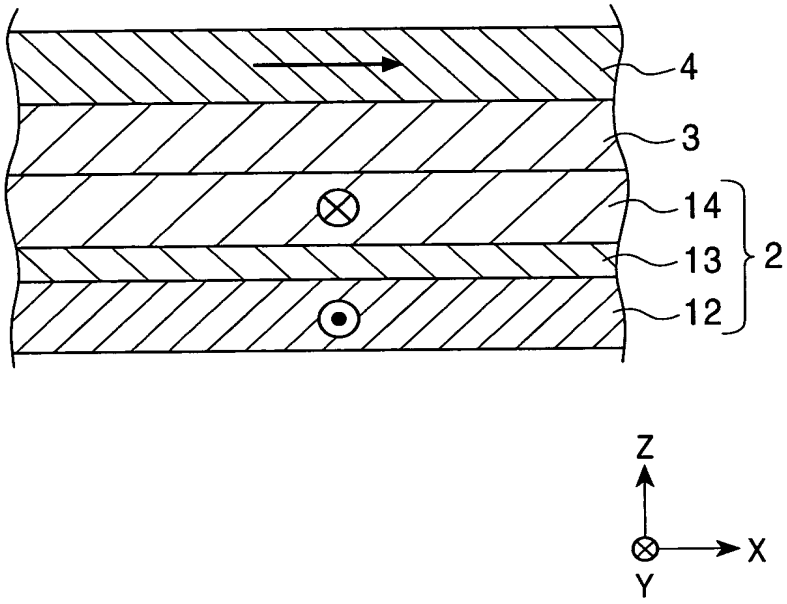
FIG. 65
PRIOR ART